Striga -
Improved management in Africa

FAO PLANT PRODUCTION AND PROTECTION PAPER

96

FOOD
AND
AGRICULTURE
ORGANIZATION
OF THE
UNITED NATIONS

Striga - Improved management in Africa

Proceedings of the FAO/OAU All-Africa
Government Consultation on *Striga* Control
Maroua, Cameroon
20-24 October 1988

Edited by
T.O. Robson
and
H.R. Broad

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Rome, 1989**

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CONTENTS

PART I - INTRODUCTORY SESSION

Introduction 5
Opening Ceremony 7
Statements by Donor Representatives 7

PART II - SUMMARY OF REPORTS AND RECOMMENDATIONS 9

Country Reports 11
Technical Session 18
FAO Package for the Small-Scale Farmer 19
All-African Programme 20
Regional Programme 20
Recommendations 21
Adoption of the Report 22
Closing Ceremony 22

PART III - COUNTRY REPORTS 25

General Overview of the Striga Problem in Africa . . . 27
Benin 29
Burkina Faso 34
Cameroon 37
Chad 41
Côte d'Ivoire 44
Gambia 48
Ghana 51
Guinea 54
Mali 58
Niger 62
Nigeria 68
Senegal 76
Sudan 80
Togo 92

PART IV - TECHNICAL SESSION 98

Research and Development Strategies for the
Control of Striga hermonthica in the Gambia
A.G. Carson 100

Recent Results of Striga Investigations in the
CILSS Integrated Pest Management Project with
Special Reference to Niger
D. Laycock 118

Potential Trap Crops as a Cultural Measure
in Striga Control for Africa
V. Parkinson, S.K. Kim, Y. Efron, L. Bello, K. Dashiell 136

IITA's Strategies to devel Striga -
Resistant Maize Germplasm
Y. Feron, S.K. Kim, V. Parkinson, N.A. Bosque-Perez 141

ICRISAT's Breeding Programme for Striga
Resistance in Sorghum and Millet in Africa
K.V. Ramaiah 154

An Approach to Cowpea Striga Control
through Plant Breeding
V.D. Aggarwal 162

Screening of Advanced Sorghum Lines for
Resistance to Striga hermonthica in Cameroon
O.P. Dangi 170

Coordinated Inter-African Phytosanitary
Regulations for Weed Control with Special
Reference to Striga
N. Nkouka 177

Improved Package for Striga Control
for the Small-Scale Farmer
L.J. Matthews 183

National Pilot Programme for Striga Control
in Cameroon
S. Njinyam 187

A Regional Programme for Striga Control
in West and Central Africa
S.S. Mboob 190

Action Programme for Striga Control
in Africa
A.L. Mbiele 195

PART V - APPENDICES

Appendix I - List of Participants 200

Appendix II - Motion of Thanks 205

PART I

INTRODUCTORY SESSION

STRIGA IN AFRICA

INTRODUCTION

The All-African Government Consultation on Striga Control was organised jointly by FAO and OAU in Maroua (Cameroon) from 20 to 24 October 1986, with the participation of 12 African countries, donor agencies and scientists from International Agricultural Research Centres (IARCs) including ICRISAT, IITA and SAFGRAD. The Consultation was in direct response to a recommendation made by the Expert Workshop on Striga held in Yaounde (Cameroon) in September 1985. This Workshop recognised the Pan-African nature of the Striga problem and requested FAO and OAU to develop an action programme for Striga control in Africa.

Two-thirds of the 73 million hectares devoted to cereal crop production in Africa are in the ecological zones where production may be seriously reduced by parasitic weeds. The greatest damage occurs in the savanna areas stretching from Cape Verde on the West Coast through west, central, east and southern Africa. These zones also constitute the major food legume producing areas in most of the countries affected. It has been estimated that crop losses due to uncontrolled Striga would average 40%, equivalent to an annual loss of seven billion dollars worth of cereals. It has been predicted that over 40% of the uninfested areas may become infested within the next five years unless immediate steps are taken to prevent further spread of Striga species. It is, therefore, pertinent that both the existing and potential threat to agriculture deserve immediate attention in order to avert major disruption in the socio-economic life of the rural population.

Striga species are noxious parasitic weeds that attack the roots of food crops such as maize, sorghum, millet, rice, fonio, cowpeas and groundnuts. In the early process of germination and growth, the parasitic weed can wipe out an entire crop. Yield losses attributed to Striga damage cannot be over-emphasised in view of the importance of the host crops in the daily diet of the people affected. The small-scale farmer, who must grow cereals to feed his family, is helpless since there have been no effective Striga control measures available up till now. In most African countries, the practice of hoeing to control weeds is not only ineffective against Striga, but is also labour-intensive and results in further depletion of nutrients and moisture in the already impoverished soil.

Until recently, governments and international agencies have failed to recognise the economic impact of Striga, let alone help the small-scale farmer in his predicament. FAO and OAU's concern for the status of food production in Africa has created awareness of this alarming problem. This present Consultation developed from a joint recommendation of the FAO/OAU Expert Workshop on Striga Control (Yaounde, Cameroon, September 1985) to coordinate and conduct long-term research into weed control. This Consultation was, therefore, arranged to address the following objectives:

1. To sensitise African governments and donors to the problem of Striga in Africa.
2. To obtain and collate the information available on distribution of the parasite, crops losses and the state of research, extension and training in Africa.
3. To develop an action programme for Striga control in Africa.

OPENING CEREMONY

The Consultation was officially opened by H.E. Dr. Solomon NFOR GWEI, the Secretary of State for Agriculture of the Republic of Cameroon. He welcomed the participants to Cameroon and to the Consultation and implored them to look for a lasting solution to the Striga problem, which should be nothing short of helping farmers overcome what he described as "the invincible enemy".

The Representative of FAO, Mr T. Mukendi, then welcomed the participants on behalf of the Director-General of FAO and called for a more concerted effort with OAU to develop and strengthen national Striga control programmes within the framework of a larger African programme. He emphasised the need for African governments to accord higher priority to plant protection for Striga control in their overall agricultural development strategies.

The Representative of OAU, Mr A.L. Mbiele, called for, among other things, the creation of an African Working Group on Weeds and the development of a Pan-African project on Striga control with strong regional, sub-regional and national components. He further emphasised the necessity for establishing an international consortium of donors for Striga control in Africa.

STATEMENTS BY DONOR REPRESENTATIVES

The Resident Representative of UNDP in Cameroon, Mr P. Coppini, gave a summary of UNDP involvement in plant protection in Cameroon and in particular in the recently approved FAO/UNDP project for Striga control. He emphasised the need to link this project to a regional programme for which UNDP funds should be sought, provided that commitments of the participating governments are forthcoming. He appealed to the donor community to increase its assistance to plant protection in Africa.

The representative of GTZ, Dr. W. Zehrer, indicated that to date, no African government had requested assistance from his government for Striga control. As a result, the activities of GTZ in this field continued to focus on minor research programmes.

The representative of Canada, Dr G. Leroux, informed the consultation of the recent creation of the Sahel Centre at the University of Laval, specialising in different areas including tropical agriculture. He indicated Canada's willingness to continue supporting Striga control in Africa.

PART II

SUMMARY OF REPORTS AND RECOMMENDATIONS

REPORT AND RECOMMENDATIONS

SUMMARY OF COUNTRY REPORTS

The participating countries emphasised the seriousness of the Striga problem in the Guinean and Sudan savanna and the Sahel zones. They expressed the need for phytosanitary measures to limit the spread of Striga through contaminated seeds, farmyard manure and farm implements. The request for the establishment of a regional Striga control programme was unanimous.

BENIN

The People's Republic of Benin is essentially an agricultural country with 85% of its population living in the rural areas. The main food crops are maize, sorghum, millet, yams, cassava and cowpeas. Although Striga has existed for a long time, the first damage was reported only in 1982, following the almost total loss of production in an area of 15 000 ha. Since then, Striga has been spreading and some farmers have been forced to abandon their infested fields.

Four species of economic importance are common in Benin. These are: S. hermonthica and S. gesnerioides on maize, sorghum, millet, rice and groundnuts; S. gesnerioides on cowpeas; and S. aspera on lowland rice. Recommended methods of Striga control are crop rotation, hand-pulling, intercropping and trap-cropping. The representative of Benin indicated the interest of the country in the formation of regional Striga control programmes with a national component.

BURKINA FASO

Agriculture is the main occupation of Burkina Faso. Therefore, major emphasis is placed on finding solutions to any factor that limits agricultural production. Striga is one such factor that has grown out of all proportion and become a national disaster. Several Striga species have been identified in the country.

Cultural control practices in farmers' fields include rotation with cotton, groundnuts, soybeans and cowpeas, also fertilizer application and uprooting Striga.

Through the efforts of the IITA/SAFGRAD Project and ICRISAT in Burkina Faso, control measures using resistant varieties have been tried in farmers' fields. Studies on Striga at the national level were recently started within the CILSS Project. However, the latter project was scheduled to terminate in 1987.

For *Striga* research to continue, international assistance is required. The Government requests continued support of the CILSS Integrated Pest Management Project which operates directly at the national level. Similarly, it is necessary for the country to train technicians and senior officers and draw up a *Striga* control programme.

Since *Striga* is also a problem for the countries neighbouring on Burkina Faso, it would be advisable for these countries to work together at finding solutions to the problem. A regional *Striga* control project comprising all West African Countries would be the most appropriate under these circumstances.

CAMEROON

The *Striga* problem in Cameroon is of economic importance in the Sudano-Sahelian zone. Food crops which constitute the local diet are severely attacked by the parasite. Host crops are sorghum, millet, maize, rice and cowpeas. *S. hermonthica* appears to be the most important species on cereals, and *S. gesnerioides* on cowpeas. There is no assessment of yield loss, but it has been estimated that in many fields of sorghum and maize losses amount to between 50 and 95%.

Research on screening for *Striga*-resistant sorghum and cowpea varieties has been initiated and some sorghum varieties such as S-35, Damougari, Framida and ICSV 1002 show a high level of tolerance.

It is hoped that the international community will initiate a regional *Striga* control project that would ensure the continuity of national pilot projects.

CHAD

Striga control in Chad is not very far advanced. Nevertheless, infestation by the parasite is of major concern. Biological and chemical control should be developed and regulations on plant protection drawn up for phytosanitary control in Chad. There is a need to train technicians in weed science since this service is non-existent.

Chad needs assistance from organisations so as to pursue a *Striga* control programme. The country would be willing to host a regional *Striga* control project.

COTE D'IVOIRE

Prior to the FAO consultancy, very little was known about Striga in the Côte d'Ivoire. Visits made between August and October 1986 revealed that the entire northern region (latitudes 9° to 11°) is infested. The zone is surrounded by countries with a long history of heavy Striga infestation.

Rice is the major cereal crop, grown not only for domestic consumption but also for export as a food commodity as well as for seed. A preliminary survey revealed that this crop is seriously threatened by Striga

Three species were identified, viz, S. hermonthica, S. aspera and S. asiatica. Many rice, maize and sorghum fields were abandoned due to Striga attack. Interviews with farmers in infested areas indicated that yield losses range from about 20% to total crop failure.

Striga is spreading at a very fast rate in Côte d'Ivoire as a result of migration of both farmers and cattle from Mali and Burkina Faso. The Government plans to take measures to limit the spread of Striga within rice growing areas.

Faced with this dreadful problem, the Government of Côte d'Ivoire is requesting FAO assistance in order to set up a coherent control programme as part of a joint project including all affected neighbouring countries. Indeed, since there are no actual so-called "borders" between African countries, and considering the extraordinary nature of Striga seed dissemination, it would be unrealistic and irrational to organise separate control programmes.

A joint project will make it possible to:

define and consolidate control methods and strategies against parasitic weeds in general and Striga in particular;

develop cooperation at the regional level to disseminate and transfer control methods to various countries;

train officers, technicians and extension workers in Striga control operations;

set up control operation facilities in each country and ensure their proper running and coordination.

GAMBIA

S. hermonthica is the most important single weed species in the Gambia, attacking maize, millet, sorghum and upland rice. Surveys showed that 75% of all cereal fields were infested with *Striga* at an average rate of 1.3 shoots/m^2. Crop losses caused by *Striga* were found to range from 20 to 35%, an annual loss of at least 10 000 tons of cereal grain valued at over US$ 900 000.

Although there are no effective traditional methods of control, farmers in the North Bank Division have reduced the incidence of *Striga* by within-season rotation of early millet and groundnuts and by allowing cattle to graze the cereal stubble and tethering them *in situ* at night during the off-season.

The Gambia has a dynamic on-going research programme on *Striga* control for which it has received funding from CILSS. The IPM Project which handles the *Striga* programme is on the point of developing a national extension programme for *Striga* control. Pilot demonstration plots have been established to test "packages" of control practices developed by the project.

Since the IPM Project terminated on 31 March 1987, other sources of funding will be required to continue the work on *Striga* which has the potential of making a major impact on Gambia's agriculture.

The Gambia supports the creation of a regional project that will ensure continuity and coordination of research efforts on *Striga* in the region.

GHANA

S. asiatica and *S. hermonthica* are the major parasitic weeds in the savanna zone and affect major cereal crops such as maize, millet and sorghum. The importance of *Striga* has increased because of the expansion in the cultivation of susceptible crops. At present, no control methods have been reported. Phytosanitary measures to prevent the movement and introduction of contaminated material to non-infested areas are suggested.

Future research requirements for the control of *Striga* should include a survey of *Striga* distribution and host range; *Striga* epidemiology; various control methods using cultural practices; and breeding for tolerant crop varieties. A strong extension component, which will create awareness of *Striga* problems among farmers and scientists capable of transferring technology to the farmers, should also be developed.

Ghana suggests the establishment of a regional/subregional programme that would coordinate and support research into Striga, with Côte d'Ivoire as the centre, catering for Ghana, Burkina Faso, Mali, Guinea, Togo and Benin.

GUINEA

Guinea is essentially an agricultural country. It has a great potential particularly on account of the favourable and varied climatic conditions. Ninety percent of the population are farmers. The economic policy of the Government is centred on agricultural development, especially the increase of food production with the ultimate aim of food self-sufficiency.

Striga is a serious problem in Guinea. The main crops attacked are rice, sorghum, millet, fonio and groundnuts. A comprehensive study will reveal whether Striga also attacks other crops in the country. No assessment is possible for the moment since no detailed Striga study has been carried out. Nevertheless, it should be noted that some fonio fields invaded by Striga have been abandoned by the farmers in the Kindia district, where annual rainfall is between 1500 and 2000 mm. No adequate control method has been developed. Hand-weeding is the only method used and the results are not encouraging in view of the parasitic nature of Striga.

The visit of the FAO Striga consultant in September 1986 enabled Guinean technicians to be made aware of the problem posed by Striga. It is now time to reflect and adopt a method of approach which will allow those involved to develop a global strategy to provide a viable solution to the problem.

MALI

Mali is situated in the Sahelian zone where the principal crops produced are millet, sorghum, maize, rice, cowpeas, groundnuts and fonio. All these crops are threatened by parasitic weeds which occur all over the country. The most important weed species are S. hermonthica, S. aspera, S. gesnerioides and Alectra vogelii. Between 75 and 100% of cereal fields are infested and yield losses range from 20 to 100%. Striga is considered the single most important pest in Mali.

Most of the progress in research on Striga is contained within the CILSS Project which unfortunately came to an end in 1987. International assistance is needed to continue the work on Striga to strengthen the national research and extension services. The creation of a regional project to ensure collaboration with different countries and research institutes will be welcome.

NIGER

Niger is located in the Sahelian zone with a population of six million, 80% of whom gain their livelihood from agriculture.

The main crops (in order of importance; millet, sorghum and cowpeas), are severely attacked by Striga. Striga is well-known to the farmers of Niger. The encroachment of the desert, the high rate of population growth and certain farming practices such as monoculture, intercropping, the absence of rotation and fallowing are all factors that aggravate Striga infestation, which is spreading to regions that were previously unaffected. The control methods employed by farmers are the use of manure, the use of urea, hand-pulling and fallowing when land is available.

Striga research is conducted as part of the CILSS Project. Some cowpea varieties, such as TN 5-781, TN 121-80 and TN 93-80, were identified as tolerant to S. gesnerioides. International assistance is needed to continue the existing research. A regional programme that will ensure networking should be given priority.

Since Niger has no national Striga specialist, it is necessary to train research, technical and extension staff for research and technology transfer at the farmer level.

NIGERIA

Among about eight species of parasitic weeds identified in Nigeria, three have assumed economic importance. These are S. hermonthica on cereals (such as maize, sorghum, millet and rice), sugar-cane, groundnuts and sesame; S. gesnerioides on cowpeas; and Alectra vogelii on groundnuts, cowpeas and, recently, soybeans. Losses may vary between 10 and 100% of crop yield. The distribution and level of infestation of these parasitic weeds in the Nigerian savanna and Sahel zones are influenced by climate, cropping systems and previous and current weed management practices. Without adequate control methods, about 40% of arable land may be infested by parasitic weeds; multiple infestation of farms by various species is now a common situation. The recommended control practices such as hand-pulling, crop rotation, fallowing, intercropping, nitrogen fertilization, maintaining an adequate plant population and timely sowing, the application of chemicals (germinators, herbicides) and the use of tolerant varieties, are not very effective unless fully integrated. Because of problems associated with each of these methods, continuous research is required. A regional programme involving collaboration between the National and International Research Centres, through international assistance, is proposed.

SENEGAL

Over 75% of the population in Senegal is rural and the country's economy is based on agriculture. The farming community for a very long time has been aware of Striga as a problem on the principal cereal crops (maize, sorghum and millet). Because of the absence of expertise on Striga, little interest has been generated and the problem has been underestimated. It was recently observed that S. hermonthica is widely distributed throughout the country.

In 1985, more than 60% of maize, sorghum and millet farms were attacked. There is currently no major research activity on Striga control, but a project in this direction is urgently needed. It is important to conduct a survey of Striga distribution and severity. Rice is an important cereal crop in Senegal but it is not known if this crop is parasitised by Striga.

International assistance is required to set up a Striga control programme, which will look into applied and adaptive research, training and extension. Senegal is fortunate to have well-structured training facilities in Dakar. The Government will, therefore, be honoured if Senegal should be selected as a base for a regional or sub-regional project on Striga control.

SUDAN

Sorghum and millet constitute 98% of the total land area under cereals and 60% of the total cultivated acreage. S. hermonthica is widely distributed and parasitises sorghum, millet, maize and sugar cane. S. densiflora and S. asiatica are restricted to Southern Kordufan and are of limited importance. Precise estimates of Striga losses are difficult to make. However, the loss may reach 100% in heavily infested fields.

Research activities on cultural control indicate that crop rotation, date and method of sowing, irrigation, trap-cropping, catch-cropping and hand-pulling all reduce the Striga seed population in the soil. Early work indicated that high levels of nitrogen delayed emergence, caused stunting of emerged shoots and reduced flowering and dry matter production of the parasite.

Applications of 2,4-D and MCPA delayed emergence, retarded rate of new infestations and increased sorghum yields. Pre- and post-emergence applications of atrazine at high rates were toxic to Striga. Oxyfluorfen, an early post-emergence directed spray, was also toxic to Striga. Combinations of nitrogen with herbicides were more effective in suppressing Striga and increasing sorghum yield than sole treatments of either nitrogen or herbicide.

Recent results indicate that ethylene and ethephon are effective in reducing Striga seed germination under both laboratory and field conditions. Breeding for resistance indicated that cultivars Tetron, P67083, IS-9830 and SR-N-39, were tolerant under low to moderate infestations.

TOGO

In Togo, 82% of the working population lives on revenue derived from agriculture. Striga species infest more than half the area under cultivation to maize, sorghum and millet, and have been reported to reduce yields by 30 to 80%. In most cases, farmers abandon their farmland whenever they have a heavy infestation. The two most common species are S. hermonthica, which is widespread in the north, and S. asiatica, which occurs in the maritime region.

Two common methods of controlling Striga are hand-pulling and crop rotation, although the latter is a long-term method. Effective quarantine to restrict dissemination of Striga seeds is suggested. International assistance is required to train extension workers and farmers and implement research on Striga control.

TECHNICAL SESSION

The technical session comprised presentations of results of agronomic research for improved Striga control at the level of the small-scale farmer as well as breeding strategies for Striga control in maize, sorghum, millet and cowpeas. The discussion on agronomic research focused on methods that aim to reduce Striga seed populations in the soil and subsequent re-infestation through the use of trap crops, the application of post-emergent herbicide and hand-pulling.

From the results of research carried out in the Gambia, the following Striga control packages were found to be effective:

a) Sorghum: the use of the tolerant variety ICSV 1002, side dressing of nitrogen at 30 kg/ha in the form of urea applied four weeks after sowing, spot spraying of emerged Striga shoots with a contact herbicide using a hand sprayer and tethering of cattle in fields after harvest whenever possible.

b) Millet: strip cropping in addition to the measures established for sorghum.

From experiments conducted in the laboratory, screenhouse and field in Nigeria, cotton, soybean and bambara nuts were identified as useful trap crops for the control of Striga species on maize. Soybeans sown in rotation or intercropped with maize effectively reduced the Striga population. A similar effect on S. hermonthica was shown when soybeans were cropped continuously for three years on an infested field and were followed by a crop of maize.

Papers on breeding strategies were presented by IITA, ICRISAT and IRA, Cameroon.

Evaluation of germplasm by the IITA maize breeding programme in the laboratory, screenhouse and field revealed genetic variability for Striga resistance. Some Striga-tolerant inbred lines and hybrid maize varieties (8322-13 and 8321-18, etc) have been identified. Further refinement of screening methodologies is important for an effective exploitation of germplasm in the breeding programme.

The IITA/SAFGRAD cowpea improvement programme has confirmed the possible existence of different physiological strains of S. gesnerioides in various countries. The cowpea variety SUVITA-2 and some of its derivatives are resistant in Burkina Faso and appear promising in Mali, Niger and Nigeria. There are good possibilities for developing broad-spectrum cowpea varieties resistant to different physiological strains of S. gesnerioides.

The ICRISAT Striga-resistance breeding programme in Africa has identified several Striga-resistant sorghum germplasms among which Framida, N-13, IS 6961, IS 9830 and Tetron were found to be the most promising. Breeding efforts to improve resistant varieties resulted in some high yielding resistant lines such as ICVS 1002 and ICVS 1007. The latter was found to have broad-spectrum resistance throughout the Striga belt.

Studies on the distribution of physiological strains of S. hermonthica have indicated the possibility of growing early sorghum varieties in millet areas where millet is normally attacked.

Research on millet indicated the possibility of identifying some resistant lines, but further research is needed.

Physiological strains of Striga continue to impose difficulties in developing stable, resistant varieties.

The screening of sorghum germplasm in the National Cereal Research and Extension project in the Cameroon identified S-35, Framida and ICVS 1002 as promising varieties resistant to S. hermonthica.

FAO PACKAGE FOR THE SMALL-SCALE FARMER

The main objective of the package is soil conservation and reduction of time and labour expended by the small-scale farmer, based on vegetation management without promoting weeds by cultural practices. The components are:

minimum movement of soil;

minimum weeding, initially only in a 20 cm band intra-row;

use of available fertilizers;

selective control of Striga within the row;

use, if available, of improved varieties showing resistance to Striga;

inter-row weeding only when Striga has been suppressed by weeds.

ALL-AFRICAN PROGRAMME

The representative of the African Phytosanitary Council presented a Pan-African action programme for Striga control with regional and sub-regional components. In the programme, emphasis was laid on:

Training of research, technical and extension staff with the support of OAU and FAO.

Research at the National Research Centres and International Research Centres, viz, IITA, ICRISAT and SAFGRAD. The components should include on-station and on-farm research and should be organised by FAO, OAU, IARCs and the National Research Institutes.

Extension by national and bilateral programmes with the support of FAO and OAU.

REGIONAL PROGRAMME

A regional coordinated programme for Striga control in West and Central Africa was proposed by FAO and funds should be sought for an initial period of five years with the following objectives:

To set up a formal networking mechanism at the regional level.

To promote the use of improved Striga control packages at the farm level.

To coordinate and support priority areas for adaptive research by strengthening the national research and extension programme.

To provide training at national and regional levels.

To disseminate information on Striga problems and control.

RECOMMENDATIONS

1. In view of inadequate information, research and extension services on the control of Striga at the farmer level, the Consultation recognised the need for international assistance to strengthen the national capability for research, training and extension.

2. Having expressed concern at the alarming rate of spread and distribution of Striga and its increasing effect on crop losses, the Consultation recommended the formation of regulations within the framework of the coordinated, inter-African phytosanitary regulations.

3. Considering the urgent need to provide the small-scale farmer with appropriate and acceptable Striga control packages, the Consultation recommended the strengthening of research at international and national levels.

4. Having taken note of the package for Striga control proposed in the meeting, the Consultation recommended that the applicability of the package be verified in various national programmes.

5. The Consultation recognised and acknowledged the progress made in Striga research through resistance breeding at the IARCs working in Africa and therefore recommended that the IARCs' Striga research should be further strengthened.

6. In view of the pan-African nature of the Striga problem, the Consultation recommended that an all-African programme with strong regional components be implemented as soon as possible.

7. The Consultation recommended that priority be given initially to developing a regional project for West and Central Africa and requested FAO/OAU to undertake a formulation mission with urgency.

8. The Consultation recommended that FAO/OAU should mobilise funds for Striga projects in other regions of Africa as soon as possible.

9. In order to ensure the maximum overall liaison and coordination of activities on Striga, the Consultation recommended that an FAO/OAU Task Force on Improved Weed Management, with emphasis on Striga, be identified, the terms of reference to be drawn up by FAO/OAU. These should be sent as soon as possible to various African countries for approval.

10. In order to mobilise funds for regional Striga programmes, the Consultation recommended that FAO/OAU convene a specific meeting of donors as a matter of urgency.

11. The Consultation commended the initiatives taken by FAO/OAU on Striga and recommended that these organisations continue the sensitisation of governments, donors and international agencies by undertaking training programmes (national and regional) and Task Force activities.

12. Recognising the significance of Striga control projects in Africa, the Consultation affirmed the commitment of governments to participate in and support regional or continental programmes on Striga control. The Consultation recommended that efforts should be made by FAO/OAU to ascertain the commitments of those countries not represented at the Consultation as a matter of urgency.

ADOPTION OF THE REPORT

The draft report of the Consultation was unanimously adopted.

CLOSING CEREMONY

Mr. Sulayman S. Mboob, FAO Regional Plant Protection Officer for Africa, who spoke on behalf of FAO, thanked all the participants and Representatives of donors and International Research Institutes and Organisations for their excellent contributions to the deliberations of the Consultation. He said it was gratifying to know that one was leaving at the end of the Consultation having achieved the main objectives of:

sentisising African Governments and Donors;

collating and assessing the information on Striga;

developing an African programme.

He noted with satisfaction the support and commitment of the African Governments to the Programme and thanked them for their renewed confidence in FAO by giving it the mandate for initiating activities to develop and implement the African Programme.

Mr. Mboob thanked the Government of Cameroon for hosting the Consultation and for providing all the excellent facilities and hospitality extended to the participants.

He emphasised the urgent need to implement sub-regional and national action programmes and, to that effect, called upon the donors and International Research Institutions to continue supporting such efforts.

The Governor of the Far-North Province, speaking on behalf of the Honourable Minister of Agriculture, expressed the hope that the information gathered from the Consultation would facilitate the setting up of national, regional and sub-regional programmes to control *Striga*. He said that the practical recommendations formulated will also enable governments to develop strategies that would be easily accessible to farmers, thereby enabling them to change from simply uprooting *Striga* plants to adopting improved methods of control.

PART III

COUNTRY REPORTS

GENERAL OVERVIEW OF THE STRIGA PROBLEM IN AFRICA

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Scientific, Technical and Research Commission
Inter-African Phytosanitary Council
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The problem of Striga in Africa involves the entire continent. Striga is a total parasite which damages between 60 and 70% of the cereal crops south of the Sahara. The region most affected stretches from West Africa to the east of Southern Africa.

The crops most affected are sorghum, millet and maize, which are not only the main crops cultivated but also the staple foods of the people in most of the region.

In addition to Striga, insect pests and pathogenic diseases also attack these crops. Together with the drought, these factors must undoubtedly contribute to the problem of undernourishment from which the majority of the people of this region are currently suffering.

Of the 30 species of Striga already recorded, 23 are reported in Africa and other species are still to be verified. The large number of species recorded and the extent of African regions affected indicate the severity of the damage caused to cereal crops and call for drastic measures to reduce this damage. Such measures might include:

a) a compilation of the scientific and technical information on Striga;

b) the establishment of an operational network of experts on Striga in Africa;

c) the creation of a multidisciplinary continental organisation on Striga to be administered by OAU and FAO. This organisation should include sub-regional and/or regional components in order to assess the problem under the various ecological conditions of the infested areas;

d) the re-orientation and follow-up of research in the field of biological control, the selection of Striga-resistant varieties of crops, the study of appropriate agricultural methods, including integrated control, and inter-governmental cooperation in Africa and outside the continent;

e) the training of African experts in this field;

f) the formation of a donors' consortium to finance Striga control in Africa; the activities to be included in a programme of work drawn from the conclusions reached at technical meetings;

g) the study of the various problems set out in reports presented by governments for appraisal.

Honourable delegates and distinguished experts, I venture to bring these ideas to your attention with the aims of locating the field of study and of understanding and assessing the Striga problem in Africa so that appropriate ways and means may be found and adopted, to minimise the problem of Striga on cereal crops in this continent. The seriousness of this pest is such that any scientific study can be undertaken only on an integrated and global basis.

I therefore wish you every success in your deliberations and call upon the experts to hold fruitful and frank scientific and technical discussions of the items on the agenda.

Thank you for your kind attention.

STRIGA IN THE PEOPLE'S REPUBLIC OF BENIN

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BASIC INFORMATION ON AGRICULTURE IN BENIN

Agriculture occupies the first place in the socio-economic life of the people. In fact, over 85% of the people live in rural areas.

In the past, the emphasis on agriculture has been placed more particularly on cash crops for export. Such crops included oil palm, cotton and coffee.

The increase in the population has compelled the people to produce food crops to attain food self-sufficiency. In order to achieve this objective, Benin has set up several training institutions in the rural areas of each of the six regions in the country.

The organisation of these research institutions enabled the research workers to realise the best conditions for good productivity and to obtain improved varieties of crops. Unfortunately, in spite of all these efforts, yields are reduced by insect pests and by parasitic plants such as Striga.

MAIN FOOD CROPS CULTIVATED

The main crops cultivated in Benin are cereals such as maize, sorghum and millet, leguminous plants such as cowpeas, and tubers such as cassava and yam.

Maize

Maize is the staple food in the south and centre of the country. Very large areas of land are devoted to its cultivation. Maize was recently introduced in the north.

Sorghum and Millet

Sorghum and millet are widely cultivated in the north where they constitute the staple diet. Large areas are cultivated in the Borgou, Atacora and Zou provinces.

Cowpeas

Cowpeas are cultivated mainly in the south and central part of the country although they are also cultivated on some farms in the north. Cowpeas are the principal and cheapest source of protein of the southerners.

Cassava

Large areas of land are planted to cassava in the south of the country. It is the second most important source of energy after maize. The recent introduction of improved varieties with resistance to bacterial and virus diseases has resulted in a significant increase in production.

Yam

In the north, yam is the second most important crop after sorghum. It is sometimes intercropped with sorghum and maize.

In addition to the above crops, groundnuts, fonio, rice and cocoyam are also cultivated.

VEGETABLE CROPS

Vegetable crops are grown mainly in the valleys where production is a permanent feature. The crops include peppers, tomatoes, okra, aubergines and onions.

INDUSTRIAL CROPS

This category includes crops produced for export such as cotton, oil palm and coffee.

FRUIT CROPS AND FOREST TREES

With the launching of the National Reforestation Campaign, extensive areas of land have been planted with fruit crops and forest trees. The species include *Eucalyptus torreliana*, *E. camaldulensis*, *Acacia auriculiformis* and *Leucaena leucocephala*. Citrus fruits such as tangerine and orange have also been planted.

THE *STRIGA* PROBLEM

For some years now, *Striga* has been a serious limitation to agricultural production in Benin. Infested areas have increased since 1982 when a total loss of crops on more than 15 000 hectares was experienced in the north of the country. Since then, *Striga* has become a great concern to the rural community.

This parasitic plant, which was first reported in the north of the country, has now spread to all other regions. There are four species, namely *Striga aspera*, *S. asiatica*, *S. hermonthica* and *S. gesnerioides*.

S. hermonthica is found in the north. *S. asiatica* and *S. gesnerioides* are the two dominant species in the centre and south of the country while *S. aspera* is sparingly distributed throughout the country.

MAIN CROPS ATTACKED

S. hermonthica infests maize, sorghum, millet, rice and groundnuts.

S. hermonthica was observed on *Brachiaria exilis* on over 20,000 hectares of fallow lands.

S. gesnerioides is found in cowpeas while *S. aspera* attacks irrigated rice and maize.

LOSSES DUE TO *STRIGA*

Losses depend on the rate of infestation and the rainfall pattern during the cropping season. In 1982, 1983 and 1984, the rainfall was as low as 650 mm instead of the 950 mm normally recorded. In 1982, there was a sharp drop in the yield of sorghum, millet and maize. The infested area was then 15 000 hectares, resulting in a loss in yield of 10 500 tons. In terms of money lost at 50 000 CFA/ha, the loss amounted to 525 000 000 (525 million) CFA or 1 312 500 US dollars. No estimate was made of the loss of yield of cowpeas. However, according to Crop Protection Service data, heavy infestations of *Striga* compelled some farmers to abandon their cowpea farms.

STRIGA CONTROL MEASURES

Up-rooting

This is one of the methods used for controlling Striga in Benin. The task is a hard one and sufficient manpower is required to carry out the operation before Striga flowers to prevent seed production. It is recommended to burn the up-rooted parasite.

Crop Rotation

Crop rotation is an effective method but is practised only on cooperative farms and by large-scale farmers. The introduction of a trap crop such as cotton, soybean or bambara groundnut encourages the suicidal germination of Striga. Unfortunately, this method is ineffective with heavy infestations.

Intercropping

During the 1982/83 growing season, the Plant Protection Service issued a technical pamphlet recommending that sorghum should be grown together with bambara groundnut. Farmers did not realise the usefulness of this recommendation because they linked the emergence of Striga with a reduction in soil fertility.

EXTENSION, TRAINING AND RESEARCH ON STRIGA

The various research activities on Striga in Benin are aimed at:

determining the distribution of Striga in the country;

identifying and recording the different species of Striga in the country;

recording the host crops;

examining the control measures.

Training sessions were organised for supervisory officers and the supporting staff of the Plant Protection Service with funds provided by FAO (Project BEN/79/004). The objective was to sensitise the people of the Striga problem. The target groups for this training were the Rural Development Authorities in the agricultural sectors, the Heads of the Sub-Sectors and the supervisors of CARDER (Regional Rural Development Action Centre). Thus, nearly 2 300 officers were sensitised and trained in 1982 in this thorny problem of Striga. Their duty was to extend the above-mentioned control methods to farmers. These activities could not continue after the end of the project.

A trial involving a variety of sorghum, "Framida: ICSV 1001 HV", tolerant to Striga, is presently being carried out at Tangieta in the north of the country.

INTERNATIONAL ASSISTANCE

The geographical distribution of Striga over several countries necessitates international cooperation for its control. To effect this cooperation it is necessary to initiate a Regional Project with a national component.

STRIGA CONTROL LEGISLATION

It is necessary to update the phytosanitary regulations in Benin. It is important to set up Quarantine Stations at the land borders where livestock in transit could be kept under surveillance for four days. This system will avert any risk of contaminating neighbouring countries with Striga seeds that might have been eaten by the livestock and ejected through the manure.

FUTURE RESEARCH AND STRIGA CONTROL STRATEGIES

Striga control depends first and foremost on a better knowledge of the biology of the many species of the parasite.

It is necessary to carry out the following activities:

a detailed survey of the various species of Striga and their host plants;

an assessment of the economic loss due to Striga;

a study of the relation between the parasite and the host plant;

a study of integrated control measures.

It is important to extend the knowledge of Striga control measures to farmers and to train supervisory personnel to ensure a rational execution of the methods that are recommended.

STRIGA IN BURKINA FASO

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BACKGROUND INFORMATION ON AGRICULTURE IN BURKINA FASO

Burkina Faso is a country whose agricultural potential should not be ignored. The basis for its development rests on agriculture and animal husbandry. Agriculture is the main occupation of the majority of the population.

For this reason, and in order to give technical support to the rural community with a view to achieving food self-sufficiency, the country has been divided into eleven regional development organisations (RDO). Some non-governmental organisations (NGO) also give considerable assistance.

A re-organisation of the rural population is under way. The emphasis is placed on the re-activation of the various farmers' organisations such as village groupings and cooperative farms. This re-organisation, which is being carried out in conformity with the five-year development plan, will put an end to traditional farming methods.

THE STRIGA PROBLEM

Burkina Faso is faced with the problem of Striga which remains one of the limiting factors to agricultural production. Fields are abandoned where attacks by Striga are severe. Investigations conducted in the eleven RDO's have revealed the presence of Striga throughout the country but at varying levels of infestation.

MAIN CROPS ATTACKED

The main crops attacked by Striga are sorghum, millet, maize, rice and cowpeas. Sorghum and millet are the most important food crops grown in Burkina Faso. These crops are attacked by two species of Striga, namely, S. asiatica and S. hermonthica, the latter being the predominant species.

Maize is cultivated on a small scale in the low rainfall areas and on a much larger scale in the west of the country. Maize is attacked by both S. asiatica and S. hermonthica,

Cowpeas are generally intercropped with cereals. Severe attacks by S. gesnerioides occur on the cowpea crop.

LOSSES DUE TO STRIGA

Investigations have been carried out on the population dynamics of Striga and the resistance of sorghum to the parasite. The results show that by up-rooting Striga from the millet, the development of S. hermonthica is reduced by an estimated 65% in the second year and 75% in the third year. It was also observed that this practice resulted in increased yield. No assessment of the losses caused by Striga has yet been made in the country but this will be undertaken.

STRIGA CONTROL MEASURES

Some methods are practised by cooperative farms and large-scale farmers, as follows:

- integrated control comprising the use of resistant crop varieties, fertilizers (eg, sorghum: N at 60 kg/ha) and up-rooting of Striga;
- crop rotation;
- the use of trap crops such as cotton, groundnuts, soybeans, cowpeas, etc.;
- chemical control - as yet in the experimental stages;
- the use of an unidentified weed (currently being studied in the laboratory) to limit the development of Striga;
- the use of an insect parasite, Smicronyx sp., as a biological control agent - as yet in the experimental stages.

EXTENSION, TRAINING AND RESEARCH

Research objectives have not yet been satisfied but the few results which have been obtained are being extended to farmers in the form of demonstrations. Within the framework of the Integrated Pest Management Project of CILSS (Permanent Interstate Committee for Drought Control in the Sahel), a pilot scheme for millet was set up two years ago. This scheme is an extension of the integrated control methods for S. hermonthica and mildew. The farmers will benefit from this scheme because they themselves serve as examples to their colleagues who do not practise these methods. With regard to training, courses are given to national technicians every year on weed management in general and Striga control in particular. They in turn train the farmers in the RDO's.

The training of national researchers at a higher international level is envisaged. One officer is already at the end of his Doctorate training course.

INTERNATIONAL ASSISTANCE

At the national level, research into Striga is being carried out through the CILSS Integrated Pest Management Project with FAO technical assistance and USAID financing. In addition, other international organisations such as ICRISAT and IITA/SAFGRAD also provide assistance. These projects are all expected to end within two years.

STRIGA CONTROL LEGISLATION

There is no legislation in Burkina Faso for the control of Striga. It is necessary to develop such legislation to permit better control of Striga and other weeds.

FUTURE RESEARCH AND STRIGA CONTROL STRATEGIES

Striga remains a problem for the country. The Integrated Pest Management Project is the only one with a mandate to work with small-scale farms. Some progress in the control of Striga has been made but unfortunately, the financing of this project ended in March 1987.

It is extremely important to provide further financing to the Integrated Pest Management Project to permit the continuation of research and extension of Striga control measures.

There are many topics to be studied, especially the assessment of losses due to Striga, chemical control and the effect of farming practices. Since Striga poses a problem to neighbouring countries, it is desirable for all these countries to cooperate in the search for remedies. The development of a regional Striga control project by West African countries would be the most appropriate action.

STRIGA IN CAMEROON

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INTRODUCTION

The part of the country most affected by Striga is the Sudano-Sahel zone that stretches from the foot of the Adamawa Plateau to Lake Chad. This region covers an area of 102,053 km^2 and has a population of more than two million. It is subject to adverse climatic conditions and for the last few years has experienced severe drought.

About 82% of the land in this region is arable; 52% of this can be used for mechanised agriculture and 22% can be irrigated by gravity if water is available.

Traditional food consists mainly of cereals eg, sorghum and millet and leguminous crops such as groundnuts, cowpeas and bambara nuts. Maize is a relatively new crop in the southern part of this region (Benoue Basin), while rice is grown under irrigation in the Logone Valley and under irrigation and rainfed conditions in the Benoue Valley.

Most of the staple crops are produced on traditional family farms for subsistence and with few external inputs. There is, however, a slow but evident adoption of borrowed techniques, especially in the farming of cotton, grown in rotation with other crops.

THE STRIGA PROBLEM

Striga now affects all the food crops grown in the area, namely sorghum, millet, maize, cowpeas and rainfed rice.

The following table shows the production data and the areas under cultivation, according to estimates by the services of the Ministry of Agriculture and the Société de Développement de Coton (SODECOTON).

CROP	CULTIVATED AREA (ha)	PRODUCTION (tons)	YIELD kg/ha
Rainy season sorghum	787 500	310 000	800
Millet	56 000	28 000	500
Dry season sorghum	110 000	77 000	700
Maize	9 500	12 350	1 300
Rainfed rice	900	1 575	1 750
Cowpeas	intercropped	100 000	-

Virtually all the area planted with rainy season sorghum and millet are affected to some extent by *S. hermonthica*. This infestation is responsible for the low yields observed for these crops. In the case of dry season sorghum, *Striga* was observed only in nursery plants.

Maize is sometimes severely attacked by *Striga* and instances of fields being abandoned because of *Striga* infestation were reported in the Benoue Region.

Cowpeas are attacked by *S. gesnerioides*. Severe attack may lead to death of the host before the parasite comes into flower. Infestation of cowpeas seems to be limited to certain areas.

No precise work has yet been carried out on the assessment of losses due to *Striga*. Estimates are based on observation of the general appearance of the crop in relation to the level of infestation by the parasite. Thus it is estimated that, on average, 15-20% of overall production is lost due to *Striga*, with maximum losses as high as 90%.

Striga is definitely the single most important parasite responsible for limiting cereal production in this region. Yet farmers seem unaware of the impact of the attack, probably because *Striga* has already done irreversible damage to the host before it appears above the soil.

STRIGA RESEARCH

Reasons for the lack of progress made in *Striga* research include the absence of *Striga* specialists and, to a certain extent, the presence of drought which has more or less overshadowed the *Striga* problem in the region.

Research carried out at the Agronomic Research Institute at Maroua has demonstrated the effect of *Striga* on sorghum, millet and cowpea productivity.

In 1983, a collection of *Striga*-resistant/tolerant varieties of sorghum was introduced from ICRISAT. *Striga*-tolerance is one of the main criteria for screening of sorghum and millet varieties. Initial results show significant differences among genotypes.

Other observations made on local varieties seem to indicate that varieties with compact panicles are more resistant to *Striga* attack than varieties with loose panicles.

In 1985, a similar trial was initiated with the introduction of a strain of cowpea showing *Striga* tolerance. The work is being carried out in areas affected by *S. gesnerioides*.

The following six varieties were identified as having some resistance to *Striga*: SUVITA-2, KVX 65-80, KVX 65-119-2, KVX 61-74, KVX 100-2, and KVX 64-54.

Improved cultivars introduced before this trial were also tested for their resistance to *Striga*. Some of them, such as TVX 1948-01F, proved to be very susceptible while others, such as TVX 3236-01 and VITA-5 showed a good level of tolerance.

FUTURE RESEARCH ACTIVITIES

The present awareness of the problem should lead to the formulation of an African Programme designed to exploit the genetic possibilities of the host plant and also to improve the understanding of the evolution of the parasite in the environment of the host. The following points need to be researched:

the geographical distribution of *Striga*;

an inventory of host plants (wild as well as cultivated);

precise data on loss of yield;

tolerance levels of local varieties;

host/parasite interaction;

the influence of rotation, nitrogen fertilizers, farmyard manure, tillage and other cultural practices, intercropping, date and density of sowing the crop and weeding of *Striga* plants;

the influence of other weeds;

the influence of rainfall;

the influence of soil texture and drainage, etc.

The training of specialists will have to precede the intensification and diversification of *Striga* research.

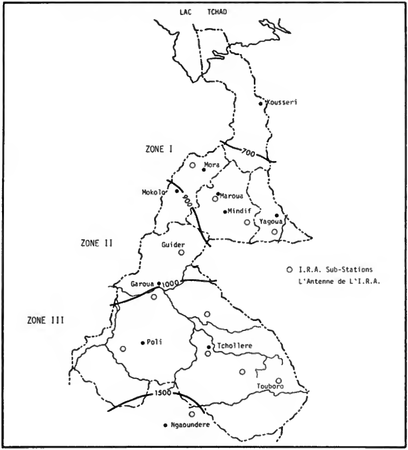
CONCLUSION

The enormity of the *Striga* problem in Cameroon is self-evident to anyone who has witnessed the infestation. There is no doubt that the implementation of a vigorous research programme here and elsewhere will surely provide the solutions so long awaited by our farmers.

However, considering the vast human and financial resources required to develop and adapt methods for controlling Striga and the difficulty of individual States to finance agricultural research, the pooling of efforts in a joint regional body seems to be the most appropriate solution.

The country of Cameroon is willing to host a Regional Project for research and the dissemination of Striga control technology.

Map showing the three climatic zones of Cameroon



STRIGA IN CHAD

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BACKGROUND INFORMATION

In Chad, agriculture is now the first priority of the State because it is the most important source of foreign exchange and of income for the rural population.

The leaders of the Third Republic laid a great deal of emphasis on agriculture in order to create favourable conditions for economic development. Even so, agriculture suffered a severe setback caused by the sad events that shook the country in addition to natural disasters such as drought, locusts and *Striga*. The problem was compounded by a shortage of trained personnel and agricultural experts.

AGRICULTURAL RESEARCH IN CHAD

Agricultural research on food crops started in 1947 with the following objectives:

increasing yield;

improving grain quality;

developing appropriate farming techniques.

As research progressed, these objectives became more specific and focused on the development of crop varieties with different maturity, morphological characteristics and resistance to diseases, *Striga* and insects.

It should be emphasised that work on food crops has been frequently interrupted due to the sudden departure of researchers to other duties and the expiration of contracts. This discontinuity has made it difficult to draw up an effective research programme.

The Division of Agricultural Research, which is the highest research body in Chad, has implemented a small but encouraging programme on *Striga* control which involves soil conservation and plant protection methods.

Striga is a problem not only in Chad but in Africa in general. The most important species in the country are Striga hermonthica found on sorghum, millet and maize, and S. gesnerioides which attacks cowpeas.

These two species are the most dangerous and there is no control measure which eliminates them completely.

STRIGA CONTROL MEASURES

In Chad, there are four methods of control, as follows:

repeated hand-pulling of Striga plants;

the use of high levels of nitrogen fertilizers;

rotation of sorghum with groundnuts and bush fallowing;

regulation of sowing date.

No chemical control method has been practised since the political disturbances, on account of the high costs involved.

Hand-pulling.

Hand-pulling is the easiest method. The operation begins as soon as the weeds appear and is repeated at weekly intervals. The limitation of this method is that it is tedious and labour-intensive.

Use of high level of nitrogen fertilizer.

The effect of nitrogen on the host is currently being studied in a Striga infested field. Three levels of nitrogen fertilizer were tested, viz, 50, 100, 150 kg/ha, applied 15, 30 and 45 days, respectively, after sowing sorghum variety C670. Satisfactory yielda were obtained with nitrogen at 150 kg/ha. Even though Striga was present in the field, infestation was not high.

Rotation.

The rotation of sorghum with groundnuts and bush-fallowing for 2 years is practised in Chad. It is effective only when strictly followed. It is the most widely used method in our research farms with a low rate of infestation. However, the limitation is that a lot of land is required.

Sowing date.

Tillage is carried out as soon as Striga seeds germinate. This method has been in operation for 3 years at the Deli Research Station. The results have been satisfactory but the drawback is that the method does not work with late-maturing varieties.

Another method being developed is the use of resistant varieties, eg, sorghum varieties 988, 708, 308 and the CG series and millet variety DBS-5.

It can be seen from the foregoing that no serious study has been carried out on Striga control. This is because of the lack of experts in this field and the necessary facilities.

The Division of Agricultural Research hopes to overcome the Striga problem by introducing new crop varieties. Biological and chemical control methods also need to be developed.

The Integrated Pest Control Service in Chad is considering this aspect of the problem.

STRIGA IN COTE D'IVOIRE

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BACKGROUND INFORMATION ON AGRICULTURE IN THE COTE D'IVOIRE

The Côte d'Ivoire is essentially an agricultural country such that agriculture constitutes the basis of the country's economic boom. Its role is and will remain essential for a long time to come in the economic, social and financial stability of the Côte d'Ivoire.

From the colonial era up to recent times, production efforts have been focused on export crops such as coffee, cocoa, rubber, coconut, oil palm, banana, pineapple, sugar-cane, etc. However, for some years now, new constraints have imposed serious modifications on the agricultural policy of the nation.

In fact, the country is not self-sufficient in cereals, particularly rice, and it is necessary to import white rice. This situation has become alarming as the population continues to grow and will double in the near future.

Thus, at present, the country lays special emphasis on food self-sufficiency. In simple terms this means encouraging, assisting and modernising agriculture in order to achieve the level of food productivity which the country has set itself.

MAIN CROPS GROWN

The staple food crops comprise four cereals (rice, maize, sorghum and millet), three tuber crops (yam, cassava and cocoyam) and plantain.

Rice

Cultivation has increased and rice is grown throughout the country due to urbanisation and high consumer demand for the crop. Of the total area of rice cultivation, rainfed rice represents 80% while irrigated rice, grown in swamps, covers 20%.

Maize

This cereal comes second after rice and is grown all over the country. In the south, it is cropped twice a year.

Millet and Sorghum

These two cereals are grown only in the north of the country.

Yam

This crop is grown mainly in the north, central and eastern regions of the country. However, a few years ago it was introduced into the south and is also spreading in the west.

Cassava

The cultivation of cassava has been intensified in the coastal region of the south but it is spreading rapidly to the centre and the west.

Cocoyam

Thia is intercropped with cocoa during the first two years for cultural reasons. Cocoyam is a popular food crop in the east of the country.

Groundnuts

This is a secondary or rotation crop grown in the north and centre of the country.

Vegetable crops

These include local vegetables such as okra, aubergine, peppers, etc. They are mostly grown together with other food crops.

INDUSTRIAL CROPS

These crops, which are destined for the export market, still play a leading role in food production. They comprise coffee, cocoa, rubber, oil palm, coconut, sugar-cane, banana poyo, pineapple and cotton. The majority of these crops are grown in the forest region, except cotton and sugar-cane which are cultivated in the savanna areas of the north and central regions.

STRIGA IN THE COTE D'IVOIRE

Striga has existed for a long time in the north of the country where sorghum, maize and millet are grown. Farmers in this region were well aware of its presence, but its density was low and it appeared to do little damage. Consequently, it was not given a great deal of attention.

Striga is reported to infest rice and other staple crops in many regions of the Côte d'Ivoire. The gravity of the situation first became apparent in the northern region of the country. In 1985, a weed scientist working with WARDA reported the infestation of rice by Striga in Odienne, Korhogo and Boundiali. The most widespread species is Striga hermonthica

At Bouake and Brobo, in the central region, S. asiatica was identified on maize and rice. S. hermonthica was found on millet, maize and sorghum at Bouna in the north-east. This situation has caused great concern to farmers in Lobis, who very often abandon heavily infested fields.

It is likely that the invasion of Striga will become more acute with the movement of livestock from neighbouring countries in which Striga occurs. For example, Odienne is on the border with Guinea, Bouna is on the border of Ghana and Burkina Faso, Korhogo and Tengrela are on the borders of Burkina Faso and Mali, all countries which have experienced heavy infestations of the weed.

MAIN CROPS ATTACKED

A concise overview of the situation shows that Striga attacks the principal cereal crops namely maize, rice, sorghum and the millets. Striga has also been found in sugar-cane plantations. Detailed research will show whether Striga attacks other food crops.

STRIGA CONTROL MEASURES

Control measures are still at an early stage. Weeding is carried out by the farmers but fields are abandoned when heavy infestations occur.

EXTENSION, TRAINING AND RESEARCH

There has been no action so far.

INTERNATIONAL ASSISTANCE

The recent mission has revealed the presence of Striga in the Côte d'Ivoire. It is therefore necessary to alert farmers, development institutions and government auithorities to the problem posed by Striga in particular and weeds in general.

LEGISLATION FOR STRIGA CONTROL

Legislation must be evolved in the Côte d'Ivoire to control the import of cereals and other seeds from neighbouring states. This means setting up a quarantine station and the establishment of phytosanitary control posts at the entry points along the borders.

FUTURE STRATEGIES

It is now recognised that Striga is likely to constitute a problem in the north of the country (in Bouna, Boundiali, Korhogo, Ferke, Odienne, etc). It is therefore necessary to carry out a general survey to discover the extent of infestation in food crops, also the geographical distribution of the weed and different species present. This would lead ultimately to the isolation and protection of cereal seed farms in the north in order to prevent the introduction and spread of the weed.

Since Striga is also a serious problem in the bordering countries, it would be desirable to work out a joint research project involving the five countries, namely Côte d'Ivoire, Burkina Faso, Mali, Guinea and Ghana. This regional project would enable the member states to make the maximum use of both the material and scientific resources which, in the case of a small-scale programme for each individual country, would be difficult to achieve.

Such a joint project would enable these countries to define and evolve a strategy for the control of weeds in general and Striga in particular. The outcome would be:

to enhance regional cooperation through the dissemination of information and the transfer of techniques to farmers and technicians and the training of extension workers;

to increase the production of cereals.

If the Côte d'Ivoire should be selected to host this project, the northern city of Korhogo would be the ideal operational base for the following reasons:

Korhogo is situated in the northern region with borders on four other countries;

Korhogo is the third largest city in the Côte d'Ivoire and has an airport and a network of roads which facilitate transport to all destinations including Abidjan, Conakry, Burkina Faso and Mali.

there is already a millet and sorghum research station at Ferke, near Korhogo.

STRIGA IN GAMBIA

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BACKGROUND INFORMATION

The Gambia lies between latitude 13° and 14° north of the equator in the Sahelian zone of Africa. It stretches for almost 400 km and is about 47 km at its widest point.

Agriculture is the backbone of the economy and engages nearly 85% of the active population. Agricultural output makes up 60% of the Gross Domestic Product.

The farming system is gradually changing from shifting cultivation to a more permanent cropping system relying on rotation and only a few years of bush fallowing. Traditional cultivation using hand-held tools is also giving way to cultivation by animal-drawn equipment.

Production of the basic cereal crops like millet, sorghum and maize has expanded in recent years at the expense of the main cash crop, groundnuts, as a reaction to the poor grain yields caused by drought and mounting pest problems. Another effect of the recent drought is that farmers are being restricted to the production of early millet even though they may prefer late millet, sorghum and maize as the staple crop.

THE STRIGA PROBLEM

Striga hermonthica is the most important weed species in the Gambia where it is found attacking maize, millet, sorghum and upland rice. Surveys showed that about 75% of all cereal fields were infested with *Striga* at an average density of 1.3 shoots per m^2. The problem is more severe in the north bank portions of MacCarthy Island and Upper River divisions. Subsequent surveys confirmed the spread of *Striga* and further indicated that the severity is increasing because of an expansion in crop production.

A second species, *S. aspera*, parasitises *Digitaria exilis* (findi).

CROP LOSSES DUE TO STRIGA

Crop losses caused by Striga determined over two consecutive years ranged from 20 to 35%. An annual loss of at least 10 000 tonnes of cereal grain is predicted, valued at over 900 000 US dollars.

STRIGA CONTROL MEASURES

Farmers in the North Bank division have developed a cropping system that appears to prevent the increase and spread of Striga. It involves the rotation of groundnuts and early millet over a single season, allowing cattle to graze the cereal stubble then tethering them in the field at night during the off-season.

The only other traditional method of controlling Striga is to carry out a second late weeding or hand-pull the parasite.

The control of Striga is considered to be a priority area of research in the weed management programme of the Integrated Pest Management (IPM) Project of CILSS in the Gambia. Several control measures have been rigorously tested in pre-extension on-farm trials and the most successful ones have been combined into a package. Pilot demonstration plots have been established in farmers' fields, with full participation by farmers, to assess the packages. The packages include the use of a tolerant variety, side dressing with urea fertilizer, spot spraying of emerged Striga shoots and tethering of cattle in the fields at night, where available. It is hoped that this technology will be adopted by other farmers, within the shortest possible time.

EXTENSION, TRAINING AND RESEARCH

The IPM Project is at the point of developing a national extension programme for Striga control which will then be supported by the Training and Visit (T & V) extension system now employed by the Ministry of Agriculture. Six technicians have been trained locally at the Diploma level in integrated pest management and are now serving as observers in the country's observation posts to monitor and survey the incidence of pests, including Striga. Their workload includes a survey of Striga, the assessment of crop loss due to Striga and the establishment of demonstration plots for Striga control.

One senior officer is currently training in weed management in the Philippines.

Research on Striga is actively pursued at research stations, observation posts and in farmers' fields. The projects include screening of varieties, estimation of crop losses, evaluation of strip cropping, intercropping and testing of control packages.

INTERNATIONAL ASSISTANCE

The Gambia is a member of CILSS and, as such, receives assistance for its work on Striga. However, the IPM Project of CILSS, which handles pest management, ended on 31st March 1987. Other sources of funding are now required to continue the vital work on Striga. The Gambia is therefore anxious to see the creation of a regional project to take over from where CILSS left off and which will ensure the continuity and coordination of Striga research.

LEGISLATION FOR STRIGA CONTROL

There is no special legislation for Striga control at present. However, there is a need for legislation under which Striga would be regarded as a Prohibited Noxious Weed requiring eradication.

FUTURE RESEARCH AND CONTROL STRATEGIES

The following areas of study are suggested:

continuation of research into cultural, varietal and chemical control measures;

development of control packages, including cropping systems aimed at reducing the incidence of Striga;

dissemination of research findings and knowledge to the small-scale farmer;

training of extension workers;

collaboration with other research institutions.

STRIGA IN GHANA

K. Ampong Nyarko

BACKGROUND INFORMATION ON AGRICULTURE IN GHANA

Agriculture in Ghana accounts for about one-half of the Gross Domestic Product. The bulk of the country's agricultural production is by smallholders using traditional techniques (hoe and cutlass). Except for rice, which is 40 to 50% mechanised, mechanised farming is relatively unimportant. The total area under cultivation is about three million hectares with over one million hectares of cocoa. Other major crops are cereals (800 000 ha), other staples (700 000 ha) and pulses and nuts (400 000 ha). Maize (about 400 000 ha) is the most important grain crop, accounting for 50 to 60% of the total production of cereals and is produced in all regions of the country. Maize production averaged some 375 000 tonnes per annum during 1970-85. Other important crops include sorghum, millet, cassava, cocoyam, yam, plantain, oil palm, groundnuts and cowpeas.

Ecologically, Ghana consists of two main zones, the forest zone, covering one-third of the country, and the Savannah zone, taking up the remaining two-thirds. The Northern Savannah (57% of the land area) has a single rainy season and annual rainfall ranging from 800 to 1200 mm with the rainfall declining from south to north. It is within this zone that Striga is important. The main crops are millet, sorghum, rice, cowpea, yam, groundnuts and tomatoes. However, soils are generally poor, with very low organic content and nutrient status. From the point of view of agriculture, the major problem in the zone is the intense, long dry season.

THE STRIGA PROBLEM

The distribution of Striga species in Ghana is quite distinct. It is a serious problem in the northern parts of the country, covering approximately all areas above latitude $9^{0}30'$N. In a recent informal survey, farmers indicated that Striga is the problem weed in the region. Species of the parasite that have been identified in Northern Ghana are S. asiatica (yellow flowers) and S. hermonthica. Farmers in this area recognise Striga as a primary yield-reducer of their food crops.

Cereal crops attacked are maize, millet and sorghum. There have been reports of Striga infestation in groundnuts to an extent where yield of the crop was affected. The parasitic weed may in some cases destroy the entire crop, especially during a period of drought when the water stress in the host already created by the parasite is aggravated by the environment. The erratic rainfall pattern and the inherent low soil fertility in these areas also enhance the effects of the parasite.

Most Striga species have a wide host range. As a result, its importance has increased where farmers grow susceptible crops every year as components of their traditional intercropping systems and rotations such as maize-sorghum-cowpeas-groundnut or maize-rice-sorghum. The increasingly difficult weed problems caused by Striga and speargrass (Imperata cylindrica) initiate the use of fallows. The local name for Striga is 'wumlim' which means 'stubborn weed'.

STRIGA CONTROL MEASURES

Farmers control Striga traditionally by hoeing and by fallowing. Fields are usually abandoned under heavy infestation. Increasing the level of fertilization has been found to reduce the impact of Striga on maize. None of the herbicides available in Ghana controls Striga.

LEGISLATION FOR STRIGA CONTROL

Phytosanitary measures to control the movement and introduction of contaminated material to non-infested areas would be necessary. Seed inspection and certification and the control of the movement of cattle from the infested areas in the country and from neighbouring countries must be vigorously pursued.

FUTURE RESEARCH AND CONTROL STRATEGIES

There is little information on the status of Striga in Ghanaian agriculture. A survey of the distribution, adaptation, host range and importance of Striga spp. on all the important food crops in Ghana needs to be carried out. Other areas that need to be looked into include its epidemiology, the use of trap crops in mulching, strip cropping, mixed cropping and the use of tolerant varieties. There is also a need to create awareness of the Striga problem among farmers and agricultural scientists.

INTERNATIONAL ASSISTANCE

Ghana, like most countries in Africa, is unable to support a research programme on Striga because of mounting debts and shortage of foreign exchange. Subsistence farmers grow a diversity of crops in their inter-cropping system and this will continue to worsen the Striga problem. There is an urgent need for research in the control of Striga but this will require international assistance for it to be effective. Since the primary purpose of research on Striga is to improve the efficiency of agriculture, there must be an effective link between researchers in the countries affected by Striga. The Government of Ghana would like to see a mechanism set up for the dissemination of information in order to speed up the transfer of technology with the greatest economy. There is an urgent need for the establishment of a regional/sub-regional centre that would coordinate and support research into Striga. A sub-regional centre based in Ivory Coast would cater for the needs of Ghana, Burkina Faso, Mali and Guinea. This location is preferred because it is centrally placed and has good road snd air networks to nearby countries. The service could be extended to Togo and Benin as the project matures. These are relatively small countries where, nonetheless, some efforts have been made to tackle the Striga problem. A sub-regional programme embracing all these countries would ensure effective control of Striga in Africa.

STRIGA IN GUINEA

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BACKGROUND INFORMATION ON AGRICULTURE IN GUINEA

Guinea is essentially an agricultural country. It has a great deal of potential, particularly with its favourable and varied climatic conditions. Ninety percent of the population are farmers. The economic policy of the Government is centred on agricultural development, especially the increase in food production with the ultimate aim of food self-sufficiency.

MAIN CROPS GROWN IN GUINEA

Rice

Three main types of rice are cultivated, as follows:

Rainfed rice: grown in regions with heavy rainfall; the area under cultivation is estimated to be 300 000 ha per year with an output between 500 and 700 kg/ha.

Lowland rice: cultivated throughout the country but particularly in Upper Guinea. 130 000 ha are cultivated annually and the yield is between 400 and 800 kg/ha.

Swamp rice: 65 000 ha are cultivated annually and the yield is around one tonne/ha.

Maize

Next in importance to rice, maize is cultivated throughout the country. The area is 145 000 ha and the average yield is 150 kg/ha.

Millet and Sorghum

These two crops are cultivated in the north-east of the country (Gaoual Koundara) and in the central region (Dabola, Dinguiraye). They meet the food requirements of the people of these regions.

Fonio (*Digitaria exilis*)

This cereal is cultivated throughout the country but especially in central Guinea where it covers 70% of cultivated land.

Cassava

Cassava is grown in all districts and more than 100 000 ha are cultivated annually with an output of 5 tonnes/ha.

Yam

This crop is grown only in the central region (Kankan, Kouroussa, Dabola, Dinguiraye and Kerouane).

Cocoyam and Potato

These are grown mainly in the south-east of the country, in Dalaba, Pita, Labe, Tougue and Mali.

Goundnuts

Groundnuts are grown over the whole country but particularly in the north-east (Koundara and Gaoual) and in the centre (Dabola and Dinguiraye). 145 000 ha are cultivated each year with a yield of 650 kg/ha.

Industrial Crops

These include coffee, cotton, sugar cane, pineapples, banana and oil palm.

Vegetable Crops

These crops are grown in Lower and Upper Guinea and include peppers, okra, aubergines, onion and foliage vegetables.

STRIGA IN GUINEA

Striga was first reported in Guinea in 1952 by Mr. J. Brun, who was then working at the Institute of Colonial Fruit Crops and Citrus Fruits in the Kindia district. This harmful parasitic plant poses a serious problem to the inhabitants of Kindia, Dabola, Dinguiraye, Gaoual, Koundara and Siguiri.

MAIN CROPS ATTACKED BY STRIGA

The main crops attacked by *Striga* are sorghum, millet, fonio and groundnuts. A comprehensive study will reveal whether *Striga* also attacks other crops in Guinea.

LOSSES CAUSED BY STRIGA

No assessment is possible for the moment since no detailed study has yet been carried out. Nevertheless, it should be noted that some fonio fields which were invaded by *Striga* were abandoned by farmers in the Kindia district where annual rainfall varies between 1,000 and 2,000 mm.

STRIGA CONTROL MEASURES

No adequate control method has been developed. Only hand-weeding is used and the results are not encouraging in view of the parasitic nature of *Striga*.

INTERNATIONAL ASSISTANCE

The visit by the FAO consultant has made Guinea technicians aware of the problem posed by *Striga*. It is now time to reflect and adopt a method of approach which will allow those involved to develop a global strategy to provide a viable solution to the problem.

LEGISLATION FOR STRIGA CONTROL

It is necessary to develop phytosanitary regulations to permit the enforcement of strict control of seeds in Guinea.

FUTURE RESEARCH AND STRIGA CONTROL STRATEGIES

It is essential:

to organise training courses for Plant Protection Service officers;

to record and identify *Striga* spp. according to natural regions and crops;

to gain a better knowledge of the biology of *Striga* spp.;

to assess the economic impact of *Striga*.

JOINT PROGRAMME

Since the problems imposed by Striga affect neighbouring countries, it would be desirable to develop a joint research project covering Guinea, Senegal, Mali and Ivory Coast.

This regional project would enable the member countries to benefit to the full from the results of research conducted in the other countries. The joint programme would enable the countries to define and develop methods for the control of weeds in general and Striga in particular in order to increase cereal production. It would also encourage cooperation at the regional level by the dissemination of information and the transfer of technology to extension workers, technicians and farmers.

If Guinea should be chosen to host the project, the Kindia region would be the ideal operational base, for the following reasons:

Kindia is situated in south-eastern Guinea and is the third city after Conakry and Kankan;

the National Plant Protection Laboratory is located in Kindia and the city is easily accessible by road from all directions such as Mali, Senegal and the Côte d'Ivoire.

STRIGA IN MALI

BACKGROUND INFORMATION ON AGRICULTURE IN MALI

Mali is a landlocked country extending from 10°N to the Tropic of Cancer and covering an area of 1 240 132 km². Most of the country comes within the Sahel.

Agriculture is the principal source of revenue for 85% of the population. Land under cultivation covers more than two million hectares.

In recent years, drought has caused widespread famine and a drop in the production of groundnuts and cotton. In an effort to achieve food self-sufficiency, the production of cereals has been expanded. However, this cereal production has been badly threatened by the spread of *Striga*.

MAIN CROPS ATTACKED BY *STRIGA*

Striga occurs on three-quarters of the area under cultivation. The main crops attacked are millet, sorghum and maize. Other host crops are: rainfed rice, especially in the southern humid zone; cowpeas, grown mainly in the central and northern parts of the country; and fonio, grown in small areas as a supplementary crop.

THE *STRIGA* PROBLEM

Striga is a threat to the important crops grown throughout the country with up to 80% of fields infested.

Millet, sorghum, maize, rainfed rice and fonio are attacked by *S. hermonthica*, *S. aspera* and *S. passengei* of which the most important is undoubtedly *S. hermonthica*.

Cowpeas are attacked by *S. gesnerioides*.

Cowpeas and groundnuts are also attacked by the parasitic weed *Alectra vogelii*, and deep-water rice is attacked by *Ramphicarpa fistulosa*.

LOSSES DUE TO *STRIGA*

Preliminary surveys at farmer level have shown that losses range between 25 and 100% of the harvest, in serious cases of infestation.

STRIGA CONTROL MEASURES

Surveys have also shown that a number of traditional control methods are carried out by the small-scale farmer. These are:

the use of nere powder (Parkia biglobosa) to treat seeds;

the use of Crotolaria seeds sown together with the cereal;

deep cultivation, burying Striga seeds well below soil level;

uprooting of Striga plants before they set seed;

increasing the level of fertilization;

rotation of cereals with non-host plants including legumes;

bush-fallowing for between 2 and 10 years;

the use of tolerant varieties auch as Segretana, or early-maturing varieties such as Souna;

intercropping cereals with legumes.

Certain of these methods have been studied and have proved ineffective against Striga (eg, nere powder). Other methods are still being studied (eg, fertilization and intercropping).

The local varieties of sorghum Segretana have shown a good level of resistance,as have Gorom Gorom and 58.57 cowpea variety.

EXTENSION, TRAINING AND RESEARCH

Extension

The control measures adopted at the Research Station (eg, up-rooting before flowering, up-rooting after the cereal harvest, fertilization) have not yet reached the level of the farmer. However, these practices have been adopted by the Integrated Pest Management Project (CILSS) in demonstration trials in certain villages where only millet is grown.

Training

At the agricultural research level, 10 technicians working on the parasites of the principal food crops, devoted 20% of their time to collecting data on Striga. This level of activity is far from sufficient, in view of the severity of Striga in the country. One senior research officer is preparing a Doctorate in France on Striga and another is preparing an M.Sc. on weed science in USA.

It must, however, be stressed that no special activity for Striga exists at the level of the National Plant Protection Service.

Training

The following programme is being carried out in Research Stations and observations posts as part of the Integrated Pest Management Project:

Millet and Sorghum

estimation of losses due to *S. hermonthica* at farmer level;

varietal resistance of millet to *S. hermonthica*;

evaluation of long-term effects of up-rooting *Striga*;

evaluation of traditional control measures against *Striga*;

influence of soil temperature on *Striga* development;

influence of intercropping of cereals with legumes on *S. hermonthica*.

Cowpeas

influence of fertilizer on *S. gesnerioides*;

varietal resistance of cowpeas to *S. gesnerioides*;

survey of *Alectra vogelii*.

INTERNATIONAL ASSISTANCE

Mali receives assistance from the CILSS Integrated Pest Management Project. This programme, which supported preliminary studies on *Striga*, came to an end on 31 March 1987. International assistance is necessary to ensure the continuance of this project and the strengthening of existing national research and extension structures.

The existence of a regional project would permit the coordination of the efforts made by the various countries of the sub-region for the control of *Striga* and, eventually, other weeds.

LEGISLATION FOR *STRIGA* CONTROL

There is no phytosanitary legislation for *Striga* control in Mali. However, it is to be hoped that a mandate will be given for a regional project to initiate legislation in this field.

FUTURE STRATEGIES

These might include the following:

research into cultural, varietal, traditional, chemical and integrated control measures;

dissemination of research findings and knowledge at the level of the small-scale farmer;

training of extension workers and farmers;

publication of technical brochures and posters on control measures;

collaboration with other research institutions and some universities;

follow-up on the epidemiology of *Striga* and other harmful weeds.

STRIGA IN NIGER

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BACKGROUND INFORMATION ON AGRICULTURE IN NIGER

Niger is a landlocked country lying more than 600 km from the sea and extends from 12^{0}N to 23^{0}N and from latitudes 0^0 to 16^{0}E. It is essentially an agricultural country with a land area of 1 267 000 km^2 and a population of 5 098 427 inhabitants (1977). The rate of increase of the population is 2.77% per annum; the estimated population for 1983 was 6 million, 90% of whom depend directly on agriculture for their livelihood.

Land use

From the point of view of land use, the country is divided into three natural regions.

To the south, bordering on Nigeria and Benin, lies the agricultural region, covering some 120 000 km which is 10% of the country. Irrigable lands are estimated at between 270 000 and 300 000 ha of which 12 000 ha are irrigated with an absolute control of water while 50 000 ha are irrigated during the dry season. The 1977-83 Five-year Development Plan envisaged that 1 000 ha of land would be developed each year as part of a state effort to contribute to food self-sufficiency.

In the central region are the grazing lands of Niger covering 30% of the land area.

In the north is the desert land which covers 60% of the country.

Soils and hydrography

In the agricultural areas, the soil is sandy and rocky; the Niger River Valley, however, has heavy soils. The river flows across the western part of the country over a distance of 550 km. Heavy soils are also found in the Dallols, the Maggia and Goulis, valleys bordering on Lake Chad and Komadoogou to the east. The agricultural area is well served by a network of roads.

Climate

The climate is of a continental Sahelian type marked by two seasons, the dry season from October to May and the hot wet season from June to September. Rainfall is often uneven in time and space.

On account of its landlocked position, poor sandy soils and the shortage of water for irrigation, Niger's agriculture is heavily dependent on climatic conditions.

Measures to cope with unfavourable natural conditions

Despite climatic uncertainties, it is anticipated that efforts made by the state in hydro-agricultural development, the intensification of off-season farming, subsidisation of certain agricultural inputs, the organisation of farmers into self-managed cooperative societies and the establishment in 1975 of the National Institute of Agronomic Research could lead Niger to food self-sufficiency.

Table 1 gives the areas under cultivation and production figures for the 1985 cropping season. The most important crop is millet followed by sorghum and cowpea. In the current year (1986) it is anticipated that grain production will meet the needs of the population.

Cultural practices

Millet, sorghum, cowpeas and groundnuts are usually intercropped. Intercropping does not increase yields of any particular crop but makes a harvest more certain. Crop rotation is commonly practised but fallowing is rare because of the shortage of land.

Organising farmers

In Niger, farmers are organised into cooperative societies at village, clan, sub-divisional, divisional and national levels. The cooperative society supplies agricultural inputs to members.

Production of selected seed

The state ensures the production of seed, starting with the breeder's seed produced by research, through the seed multiplication centres, to multiplication by farmers themselves.

Price Policy

At the end of each cropping season, a national board fixes the maximum prices to farmers for the major agricultural produce.

Table 1. Area under cultivation and total production in Niger in 1985

Crop	Area under cultivation (ha)	Total production (tons)
Millet	3 153 777	1 451 416
Sorghum	1 148 101	329 414
Cowpea	1 721 629	128 907
Groundnuts	90 431	8 728
Rainy season rice	10 603	13 282
Dry season rice	7 039	26 338
Maize	7 241	2 671
Wheat	1 558	3 509
Bambara groundnuts	7 831	3 620
Cassava	15 289	189 904
Sweet potatoes	3 462	35 189
Sugar cane	6 669	149 368
Onions	3 006	62 108
Cyperus (souchet)	1 161	945
Cotton	4 482	6 214
Fonio	1 965	424
Potatoes	236	1 903
Tomatoes	1 446	14 087
Other vegetable crops	1 661	-
Sesame	1 418	1 418
Tobacco	1 310	500
Dolichos	6 063	16
Sweet pepper	86	7 678

Source: Seminars, Ministry of Agriculture, Maradi, Niger, 3 - 13 March, 1986

Organisation of the Ministry of Agriculture

In addition to the Minister, there are also Departments of Agricultural Production, of Rural Engineering, of Studies, Programming and Agricultural Statistics, of Plant Protection and of Administrative and Financial Affairs.

In addition to the national level of administration, there are, at the regional level, Divisional Directorates of Agriculture and also sub-divisional, rural council and district services.

ORGANISATION OF THE PLANT PROTECTION SERVICE

The Department of Plant Protection, the Legislative and Phytosanitary Control Services, the Supervisory and Applied Research Service and the Phytosanitary Interventions and Equipment Service are organised at the national level. The Department of Plant Protection is also represented in the divisions.

In addition to the ministry staff, the Department of Plant Protection has trained village squads (about ten farmers per village) in phytosanitary treatments. They are provided with equipment and products by the state.

Furthermore, each division possesses truck-mounted equipment and, at the national level, three CESSNA aircraft are used for large-scale operations.

Regarding research, we have the National Institute of Agronomic Research (INRAN) which maintains several stations and outposts in various ecological zones. The plant protection section also has entomology and pathology sub-sections.

The country has a *Striga* programme which is financed by the CILSS Integrated Pest Management (IPM) Project against enemies of food crops in the Sahel and would like to see this programme strengthened by international assistance. As with the IPM Project, this programme could be upgraded to a regional one, from the standpoint of both research and extension.

THE *STRIGA* PROBLEM IN NIGER

The following parasitic weeds occur in Niger: *Striga hermonthica* on millet, sorghum and maize, *S. gesnerioides* on cowpeas and *Orobanche* on tomatoes. Thus *Striga* poses a threat mainly to food crops.

The combined effects of the advancing drought plus the high rate of population growth have caused an increase in the intensity of

Striga infestations as well as a spread to new areas. Thus for the first time, in 1985, S. gesnerioides was observed at the Kolo and Bengou research stations.

Certain cultural practices followed by farmers tend to promote Striga. For example, the monoculture of millet or sorghum year after year causes an increase in the number of Striga seeds in the soil. The intercropping of millet with cowpeas leads to the infestation of fields by both S. hermonthica and S. gesnerioides. Leaving millet or sorghum stems standing after harvest, or cutting the stems just above the ground either prior to or shortly after harvest, enable S. hermonthica to complete its cycle, thus increasing seed production by the weed.

MAJOR CROPS ATTACKED BY STRIGA

In Niger, the most important crop attacked by Striga is millet, followed by sorghum and cowpeas. The degree of infestation varies from one geographical area to another.

On depleted sandy soils of the moderately populated Maradi and Zinder Divisions where cowpeas are often intercropped with millet, attacks by S. hermonthica on millet and S. gesnerioides on cowpeas are very serious.

In the south of Dosso Division, S. hermonthica attacks millet, sorghum and maize on heavy soils, while S. gesnerioides attacks cowpeas. In Niamey Division, Striga infestations are more serious on cowpeas than on millet or sorghum.

LOSSES DUE TO STRIGA

There are no records for Niger. However, parasitism is more serious on cowpeas than on millet. In general, Striga appears on millet as the ears emerge, whereas Striga appears earlier in cowpeas.

On irrigated cowpeas, ie, sown following the initial irrigation, Striga appeared from 62 - 83 days later in 1982 and from 67 - 90 days later in 1985. During the wet season, however, when cowpeas were sown as early as possible after the second rains, Striga appeared after 40 - 63 days in 1982 and 33 - 62 days in 1985. In maize sown after the first rains, Striga emerged 55 - 64 days later and for maize sown late in the season, Striga emerged 34 - 46 days later.

STRIGA CONTROL MEASURES

In certain areas of Niger, farmers up-root millet and sorghum that has been infested with Striga, sometimes after grain production. The weed may not always be destroyed by burning.

The use of farm manure helps to check Striga infestation. The use of urea on millet and sorghum, where funds permit and rainfall is adequate, checks S. hermonthica.

When land becomes unproductive as a result of Striga infestation, it may be left to lie fallow if sufficient land is available.

EXTENSION, TRAINING AND RESEARCH

Extension work on Striga has only recently been started in Niger. There are no weed scientists. However, there is a pathologist working on Striga and one student. It is therefore imperative to train researchers and technicians in this area.

Research on cowpea Striga has centred mainly on resistant varieties. Two factors have been considered: the date of emergence of Striga and the number of Striga that have emerged from the soil prior to harvesting.

In 1983, a survey was carried out in the Zinder Division to determine the geographical distribution and density of S. hermonthica on millet and S. gesnerioides on cowpeas. All the fields were infested. It was noticed that there were more Striga plants on sandy soils than on heavy soils. Also, there was no Striga on sorghum grown either alone or intercropped with millet. The number of Striga per m^2 in millet varied from 1.45 to 48, with an overall mean of 16.6, and in cowpeas varied from 0.5 to 30.7 with an overall mean of 7.7.

The emergence of Striga depends on the length of time that the soil remains moist before sowing. The longer the period, the shorter the time for Striga to emerge. The emergence of Striga showed no significant difference between varieties of either millet or cowpeas.

In another study, cowpea varieties TN-5-78, TN-121-80 and TN-93-80 were equal, or superior, to SUVITA 2, which ICRISAT found to be a resistant variety in Burkina Faso.

In a study on biological control, microorganisms were extracted from isolated Striga plants which had died before attaining physiological maturity.

STRIGA IN NIGERIA

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BASIC INFORMATION IN AGRICULTURE

About 80% of the Nigerian population is presently engaged in agriculture-based occupations. Until recently, over 90% of those engaged in farming were subsistence small-scale farmers, with barely more than two hectare holdings. These farmers, who are usually referred to as "hoe-farmers" (Ogborn, 1972), use simple implements such as hoes and cutlasses for clearing land, cultivating, weeding, etc. The recent fall in the price of oil has resulted in an increase in the number of large-scale farmers with holdings between 5 and 3000 ha. Such producers include private individuals (mainly ex-politicians, retired civil servants, military officers and traditional rulers) and private companies which produce raw materials for various agriculture-based industries. These producers embark on partial mechanisation, usually restricted to cultivation, sowing, pesticide application and sometimes weeding. Few large-scale producers use combine harvesters.

The Nigerian Savanna covers about one-third of the total land area of Nigeria. It consists of about five ecological zones from the south to the north, namely Derived, Southern and Northern Guinea, Sudan Savannas and the Sahel. About 75% of the farming population live and work in these zones, which also constitute the major cereal producing area of the country.

The most important cereal is sorghum which is grown on about 5 million ha, with an annual production of 3.4 million metric tonnes. In 1984, the production of millet and maize was about 3 and 2.5 million metric tonnes, respectively. Other major cereal crops of the Savanna include rice and wheat. Production of these crops has increased considerably since the ban on importation. The production of wheat, however, is confined to the drier, colder part of the northern NGS, SS and Sahel zones. Of great importance are the leguminous crops such as cowpeas, groundnuts and, more recently, soybean, since they constitute the major and cheapest sources of protein in the diet. With the recent escalation in the price of meat products in the country, protein from leguminous plants, especially cowpeas and groundnuts, constitutes at least one-fifth of the daily diet.

THE *STRIGA* PROBLEM

The three major parasitic weeds which have assumed economic importance in the Nigerian Savannas are *Striga hermonthica* in cereals (sorghum, maize, millet, rice and sugar-cane), *S. gesnerioides* in cowpeas and *Alectra vogelii* in cowpeas, groundnuts and recently in soybeans. Losses of between 10 and 91% have been attributed to *S. hermonthica* in cereals. An average annual loss of 39% in sorghum grain yield is equivalent to 250 million dollars of food loss in Nigeria, for sorghum alone. Groundnuts sown early produce only 15% of potential pod yield as a result of parasitism by *A. vogelii*.

S. hermonthica occurs in all the Savanna and Sahel zones of Nigeria. The parasite attacks maize and sorghum in all the ecological zones, although virulence is less on sorghum in the Sudan Savanna. Late millet (maiwa) is parasitised in the Southern and Northern Guinea Savannas, but early millet is attacked only in the Southern Guinea and Sudan Savanna zones. The existence of ecologically specific strains has been reported. Host-specificity has also been suggested, but observations made so far indicate that the sorghum strain attacks all the cereal crops and other grasses such as *Pennisetum* spp., *Eragrostis* spp. and *Cynodon dactylon*. *S. hermonthica* has also been observed to attack groundnut and sesame (Ogborn, 1972; Parkingson, personal communication).

Until recently, *S. gesnerioides* was mainly restricted to the Sudan Savannas. However, there have been regular reports of total failure of cowpea crops in some parts of the Northern Guinea Savanna in the past four years. *S. gesnerioides* was also observed on *Tephrosia* sp., a weed.

A. vogelii occurs in the Northern Guinea and Sudan Savanna and Sahel zones. It is the major and most common parasite of cowpeas in the Northern Guinea Savanna. The first reports on the severe effect of this parasite on groundnuts came 10 years ago from the Sudan Savanna and Sahel zones. In the last few years, groundnut crops in the Northern Guinea Savanna have been seriously infested. This is due to the erratic and unreliable rainfall which has usually caused a delay in sowing. Late-sown groundnut and soybean crops can be completely wiped out by this parasite.

With this rapid spread, it is estimated that over 40% of arable land will be infested by parasitic weeds within the next ten years.

A major problem that has been observed recently is multiple infestation of two or three parasitic weeds on various farmers' fields. The recent trend in the use of machinery for land cultivation has enhanced the spread of these parasites. Many farmers have had to abandon farms within five years of heavy investments in land clearance because of the occurrence of parasitic weeds. Transfer of the seeds in irrigation water has also rendered various irrigated lands uncultivable. In a situation where there is multiple infestation by parasites, crop rotation and inter-cropping may not be suitable control practices, especially in crop mixtures like cereal-cereal and cereal-legume.

STRIGA CONTROL MEASURES

The control methods recently suggested by IAR, Samaru, for S. hermonthica include cultural use of tolerant/resistant varieties and chemicals. Integration of these methods has proved very effective. Farmers in Nigeria mainly control Striga by hand-pulling and hoeing. The light infestation of one or two plants per stand is tolerated while only the heavy infestations are either hand-pulled or hoe-weeded. For effective mechanical control, about three to four operations may be necessary. It has been estimated that about five years of control effort will be required to eliminate Striga from a plot that has been badly infested. Post-emergence weed control does not, however, obviate the losses that would occur through the damage caused by the parasites before emergence. Symptoms of Striga infection on maize and sorghum were observed three and four weeks before the emergence of the parasite. Similarly, the same situation obtained for parasitism by Alectra. S. gesnerioides has even been observed to flower underground.

The use of high nitrogen fertilizer has proved very effective in preventing complete crop loss, if applied as soon as the symptoms are observed. Urea as a source has proved more useful than calcium ammonium nitrate. However, this may be very expensive, with the privatisation of fertilizer sales in Nigeria and the removal of export subsidies.

Stubble cultivation as soon as the host is harvested and before Striga produces seeds would help to reduce the population in the subsequent season, but this is only effective with large-scale farming where tractor-mounted machinery is available. An alternative to stubble cultivation is the use of foliar-acting herbicides either in direct applications while the host is still on the field or overall applications as soon as the host is harvested.

Multiple infestation by the parasites and their wide host range will preclude effective control through the use of fallow, crop rotation and crop mixture.

The use of germinators, viz, ethephon, GR_7 and 28, to induce abortive germination of S. hermonthica has not produced consistent results and not without practical limitations. Such limitations include the timing of the application to ensure adequate preconditioning of Striga seeds and effective application methods.

The cost of the germinators and the subsequent operations required might be too great for the farmer to bear.

The search for foliar-acting herbicides, which started at Samaru in 1967, led to the identification of 18 selective herbicides with definite foliage activity. The subsequent recommendation on weekly spot spraying of foliar-acting herbicides such as oleoametryne and oleolinuron on light Striga infestation using Intermittent Directed Foliar Application (IDFOLA) was not acceptable to farmers for one major reason. The level of infestation at which IDFOLA is feasible is considered tolerable by farmers. At a higher level of infestation, the method becomes labour-intensive and expensive. However, it is effective in the dry season and also has the advantage of selective Striga control in crop mixtures. When used to supplement other methods, it controlled the few stands of Striga in the field and prevented subsequent build-up of the parasite.

Directed application of foliar-acting herbicides to Striga gave effective reduction of the parasite provided it is combined with other measures such as the use of resistant/tolerant varieties, high N level and the correct plant population. In spite of mixing foliar-acting chemicals such as bromoxynil, dimethametryne and dicamba with soil residual herbicides like atrazine and cyanazine, multiple application will be required to prevent seed production completely.

The development of elite pure lines of sorghum with resistance to Striga and with acceptable grain-quality was accomplished using some of the early selections such as SRN 4841 and Framida. At IAR, Samaru, four varieties, L187 (long-season), RZ1 and YG5760 (medium-season) and BES (short-season) were found resistant, while three varieties, namely FFBL (long season) and HP3 and HP8 (short-season) were tolerant on natural Striga-infested plots. None of the varieties tested was, however, immune, and subsequently emerging Striga plants would need to be controlled in order to prevent re-infestation. Reports of breakdown in tolerance of some of the varieties have, however, been received from farmers and, therefore, require serious attention. IITA has also identified some resistant hybrid maize varieties. The level of resistance has been improved upon through gene recombination, which is being tested on various farmers' fields for confirmation.

The cowpea variety, SUVITA-2, which was reported resistant to S. gesnerioides, was parasitised in Nigeria. However, crosses of SUVITA-2 with other lines/varieties have exhibited acceptable resistance in the country. Varieties IAR 81-27, IT82D-666 and IT82D-667 have been reported to support the least number of Striga plants. Work on the resistance of cowpeas to Alectra has just been initiated.

In view of the fact that no known method has completely controlled parasitic weeds, a document suggesting the combination of available methods was produced about four years ago. The integrated method of control of S. hermonthica has not been popular with the farmers due to inadequate on-farm demonstrations to prove its authenticity. Limitations in terms of funding constitute a major bottleneck in establishing on-farm demonstration trials.

FUTURE RESEARCH AND CONTROL STRATEGY

It is obvious that parasitic weeds may thwart various governments' efforts at self-sufficiency, if nothing is done to arrest the situation immediately. The increase in distribution of the parasite appears to correspond with expansion in cultivated areas, especially in the ecological zones where hosts are grown. Maize, which was mainly a host in the Southern Guinea Savanna, is now severely parasitised in the Sudan Savanna, due to the expansion of maize programmes to that ecological zone. A similar explanation is true for the increase in areas of infestation by S. gesnerioides and Alectra. In order to arrest the devastation being caused by the parasitic weeds, the following areas need immediate attention:

on-farm testing of integrated control measures based on existing research findings. This would facilitate the transfer of available technology while eliciting information on the limitation of the components of packages;

further evaluation of various agronomic components of the package in order to identify those most socio-economically acceptable to the farmers;

continuous evaluation and development of resistant and tolerant lines in order to ensure availability of materials in case of breakdown. Some of the parasitic weeds are cross-pollinated, and might result in genetic diversity. Such a complicated situation requires continuious effort in breeding programmes.

INTERNATIONAL ASSISTANCE

Nigeria is a large country containing all the ecological zones that support many parasitic weed species. Unfortunately, because of the recent economic recession withing the country, the need for raw materials from agriculture has increased, putting greater pressure on the agricultural sector. However, available resources are inadequate to support most of the research projects that require immediate attention. International assistance, complemented by home effort, is needed to be able to undertake a meaningful programme which would arrest the threat to our goal of self-sufficiency. Nigeria, through its research institutes and other international institutes such as IITA and ICRISAT, will be able to collaborate with other nations through provision of information, materials and adequate training to facilitate the attainment of effective control of parasitic weeds. In order to ensure effective monitoring of the activities of various participants, regional or subregional centres should be established. It is hoped that such centres will coordinate activities, collate results and translate such results into an adaptable form for farmer use.

Effective on-farm projects should be conducted in order to extend the new technology, elicit problems associated with adoption of the new technology for further modification within the package and finalise the adoption process.

The centre should be able to assess the impact of the project on the client at the end of each exercise.

In order to be able to carry out the project effectively, the assistance of FAO through its donors is essential. A project proposal subject to modification has been submitted.

Table 1. Status of cultivated hosts in northern Nigeria.

Zone	S. Guinea	N. Guinea	Sudan
Rainfall pattern	Intense bimodal	Intense monomodal	Light monomodal
Crop Pennisetum millets			
gero (dln sown early harvested in rains)	not grown	very resistant	host[1]
maiwa (dls harvested after end of rains)	host	host	not grown
dauro (sown late harvested dry)	not grown	host	not grown
sorghum (dls)	host	host	host
maize	host[1]	susceptible[2]	host
rice (rainfed)	host	very resistant[2]	host
sugar-cane	host[3]	host[3]	host[3]

1. Harvested in the dry season or inter-modal drought.
2. Harvested during the rains.
3. First planting only.

Source: Ogborn, 1979

Table 2. Effect of nitrogen on yield and Striga emergence in millet.

Nitrogen (kg N/ha)	Grain weight (kg/ha)	Dry matter (kg/ha)	Striga ('000/ha)
45	676	4845	5.95
135	949	8692	0.99
LSD at 5%	263	1769	3.14

Source: Mansfield, 1982

Table 3. *Striga* count/sorghum stand at 9 weeks after sowing at Bida.

Herbicides	Rate (kg a.i./ha)	Variety L 187		Var. SRN 4841		Local var.	
		N1	N2	N1	N2	N1	N2
dicamba + cyanazine	1 + 1	0	3	2	0	5	6
bromoxynil + cyanazine	1 + 1	2	3	3	1	3	5
dimethametryne + cyanazine	1 + 1	2	2	2	1	9	7
dimethametryne + atrazine	1 + 1	2	1	1	0	7	7
hoe-weeded control		1	0	1	1	6	5

N1 = 60 kg N/ha N2 = 100 kg N/ha Source: Bakut *et al*. 1985

Table 4. *Striga* count/sorghum stand at Agaie (local variety).

Herbicides	Rate (kg a.i./ha)	9 WAP		12 WAP*	
		N1	N2	N1	N2
dicamba + cyanazine	1 + 1	11	13	22	5
bromoxynil + cyanazine	1 + 1	30	15	30	15
dimethametryne + cyanazine	1 + 1	24	21	31	6
dimethametryne + atrazine	1 + 1	17	16	25	5
hoe-weeded control		24	14	28	8

N1 = 60 kg N/ha N2 = 100 kg N/ha
*WAP = weeks after planting Source: Bakut *et al*. 1985

STRIGA IN SENEGAL

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BACKGROUND INFORMATION ON AGRICULTURE

More than 74% of the population of Senegal live in the rural areas and agriculture is the backbone of the economy. Agricultural production accounts, on average, for 18% of the gross domestic product and represents 45 to 60% of the production of the primary sector.

Cereals such as millet, sorghum, rice and maize are the main food crops. Cash crops are mainly groundnuts and cotton. Vegetable crops, which are gaining in importance, are produced mainly around the major cities and efforts are now being made to improve production and organise marketing facilities. Fruit production is somewhat diversified but is still to be organised.

Table 1. Cultivated areas and production of the main crops in Senegal (1982 - 1983).

	FOOD CROPS				COMMERCIAL CROPS		VEGETABLE CROPS
	Millet/ Sorghum	Rice	Maize	Cowpeas	G/nuts	Cotton	
Area ('000 ha)	1176.8	71.4	76.2	68.2	1081	31.9	6.9
Production ('000 tons)	736.4	103.3	86.3	28.7	882.8	41	107

Source: Readjusted Fifth Plan for Economic and Social Development (1981 - 1985)

The national production level for staple commodities, in particular cereals, falls short of consumer requirements. Cereal production in 1982 recorded a deficit of 296 000 tons. The priority of the Economic and Social Development Plan is to increase food production gradually in order to attain the objective of food self-sufficiency. In addition to the efforts devoted during previous plans to improve rain-fed crop production, emphasis will henceforth be laid on the development of irrigated crops.

THE *STRIGA* PROBLEM

For a very long time, Senegalese farmers have been aware of *Striga* attacks on millet, sorghum and rice crops. As early as the 60s, agronomists discovered the problem when they noticed serious cases of *Striga* attack in Bambey, Nioro du Rip, Sinthiou Maleme and in the Tambacounda region. However, these observations were not followed by any major studies designed to collect precise data on the scope of *Striga* infestation on crops.

Dr. A.T. Ba of the Department of Plant Biology at the University of Dakar points out that the parasite is rampant throughout the country and poses a serious problem in the North-Central regions (Djourbel, Thies and Louga). During a support mission by Prof. L.J. Musselman in 1985, *Striga* infestations were observed in most of the fields visited in Upper Casamance, Eastern and Central Senegal, and in the Djourbel Region. A survey, initiated that year to assess the extent of *Striga* infestation, was conducted in the Kolda Region and in two areas of the Kaolack Region. It showed that 60.7% of the 308 fields visited were infested by *Striga hermonthica* with 24 and 44% heavily infested.

The survey has to be continued and extended to other areas so that complete data can be gathered on the importance of infestations and the distribution of the parasite.

MAIN CROPS ATTACKED

The main crops infested by *S. hermonthica* are early millet (Souna), grown in the Centre and North of the country, late millet (Sanio) and sorghum and maize in the South and East. Infestations are more serious in crops grown in monoculture. *S. aspera* was observed in isolated cases on maize in 1985 and 1986. *S. hermonthica* and *S. aspera* were observed on upland rice in a region in Central Casamance, but there is no evidence of the parasite on lowland rice. *S. gesnerioides* was not found on cowpeas in Senegal but on species belonging to the Convolvulaceae family (*Ipomoea vagans* and *I. pescaprae*) in the Centre and North as well as the Cape Verde Region.

LOSSES DUE TO *STRIGA*

There has been no attempt to evaluate the losses due to *Striga*. Such evaluation would be of great use since it would complement the data on the incidence and severity of attacks as well as on the geographical distribution of the parasite.

EXTENSION, TRAINING AND RESEARCH

Until now, agricultural experts have not paid adequate attention to the Striga problem, probably because specialists in the area were not available and little was known about the economic impact of the parasite. The only research of importance being conducted concerns the biological aspects on which Professor A.T. Ba of the University of Dakar is presently working. It is necessary to intensify research on the agronomic aspects so as to propose short-term solutions that can be applied by small-scale farmers.

A Striga control training programme may be set up based on the recommendations made by Dr. Musselman after his consultation mission in August 1985. This programme comprises various levels, namely:

a) intensive training of short duration for research technicians;

b) training courses in control methods for technicians and extension workers;

c) information sessions and demonstration activities for small-scale farmers;

The Dakar Plant Protection Training Centre (15 km along Route de Ruffisque) is an ideal site for the development of such a programme, especially at the (b) and (c) levels. The available infrastructure and equipment are suitable for both a national project and a regional or sub-regional project.

INTERNATIONAL ASSISTANCE

Within the framework of cooperation between the University of Dakar and the Office of International Cooperation and Development, Old Dominion University (USA), aid has been granted for studies on the biology of S. aspera.

More assistance is necessary for consolidating and intensifying the applied research, training and dissemination of information activities for Striga control. If efforts were coordinated at the sub-regional level, it would doubtless be easy to find satisfactory solutions to the complex Striga problem.

LEGISLATION

Senegal has fairly comprehensive regulations concerning phytosanitary protection.

> Decree No 60-122 of 10 March 1960 makes it compulsory to control animal and plant parasites in Senegal.
>
> Order No 14308 MER of 3 October 1966 makes it compulsory to protect stored seeds and grains.

Other decrees and orders concern the regulation of pesticides or the importation of plant materials (potatoes, cassava cuttings, etc.).

Some of these regulations must be amended in order to meet international standards. There are no specific provisions for *Striga* but this should be included in the amended order after consultation with all the countries concerned.

FUTURE RESEARCH AND *STRIGA* CONTROL STRATEGIES

Research, training and extension work are the main areas on which attention shoud be focused in order to find satisfactory solutions to the *Striga* problem. With regard to applied research and control, priority should be given to the following projects:

> a survey aimed at assessing the importance of the weed and determining its geographical distribution;
>
> assessment of losses due to *Striga*;
>
> information campaigns and pre-extension work on the risks of re-infestation and on the methods and systems by which *Striga* infestations, and the losses due to the parasite, may be reduced;
>
> demonstration trials to show resistant or tolerant varieties;
>
> experiments to identify cheap herbicides that are both selective and effective;
>
> studies on the ecological and agronomic factors that influence the development of *Striga* and the application of measures to reduce its attacks.

STRIGA IN THE SUDAN

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INTRODUCTION

The genus *Striga* includes important parasitic weeds of many warm season grasses (Nelson, 1958). It is a genus of about 30 species with many sub-specific variants (Wilson-Jones, 1955; Lakshami and Jayachandra, 1979; Parker and Reid, 1979; Musselman, 1980). However, taking into account the global economic loss caused to cereal crops, *S. asiatica*, *S. hermonthica* and *S. densiflora* are the most important species (Musselman, 1980). All three species have been reported in the Sudan. *S. asiatica* and *S. densiflora* are of limited importance and they are restricted to Southern Kerdofan (Khidir, 1983a). These two species could be a potential problem especially as no quarantine measures are enforced. On the other hand, *S. hermonthica* is widely distributed as a parasite of grain sorghum and pearl millet (*Pennisetum typhoides*).

Sorghum and millet are the most important cereal food crops in the Sudan. These two crops are widely distributed in the country and they are produced under a wide range of soil and climatic conditions. The area cultivated with these crops constitutes 98% of the total area under cereals and 60% of the total cultivated acreage (see Table 1). The bulk of sorghum and millet are sown in the rainfed areas, but a considerable proportion is produced in the irrigated sector (see Table 2). The main areas of production are shown in Fig. 1.

Table 1. Area, production and average yield of important cereals in the Sudan (average 1983/84 - 1984/85).

Crop	Area ('000 ha)	Production ('000 t)	Yield (kg/ha)
sorghum	3692 (74%)	1909 (80%)	517
millet	1210 (24%)	328 (14%)	271
wheat	116 (2%)	152 (6%)	1310

The yields of sorghum and millet are generally low and are far below figures from developed countries. Furthermore, their production in large areas in the country is besieged by *S. hermonthica* (Hamdoun and Babiker, 1978). With the possible exception of birds, *S. hermonthica* may be the most important cause of yield reduction in sorghum and millet in the whole of Africa (Khidir, 1983b). Precise estimates of crop losses are difficult to make, but the loss may reach 70 - 100% in heavily infested fields. In some parts of the Sudan, farmers abandoned their fields because of *Striga* infestation (Andrews, 1947; Last, 1960a; Kambal, 1979; Khidir, 1983b).

Table 2. Area, production and average yield of sorghum in different sectors (average of 1983/84 - 1984/85).

Sector	Area ('000 ha)	Production ('000 t)	Yield (kg/ha)
irrigated	270 (7%)	283 (15%)	1038
MCF	2251 (61%)	1187 (62%)	514
traditional	116 (2%)	152 (6%)	1310
Total	3692	1909	Average 643

Recent drought conditions in Africa and immigration of citizens of many neighbouring countries into the Sudan have increased the demand on sorghum and millet and made them very valuable commodities. Hence the control of *Striga* is mandatory for profitable production and the curtailment of famine and associated socio-economic problems.

STRIGA CONTROL MEASURES

Control of *Striga* by the usual methods of weed control is difficult (Khidir, 1983a). The difficulty has been attributed to the production of numerous dormant, long-lived seeds, their ease of dissemination, their distribution in the soil and their germination requirements (Andrews, 1947; Khidir, 1983b; Bebawi and Elhag, 1983).

In the Sudan, research activities have been centred on cultural methods, the use of fertilizers, herbicides and fertilizer-herbicide combinations, germination stimulants, resistant varieties and, most recently, biological control.

Cultural methods

The influence of rotation, date and method of sowing, irrigation, trap cropping, catch cropping and hand-pulling on parasitism have been investigated by a number of workers (Andrews, 1945, 1947; Wilson-Jones, 1953a; Last, 1960a, 1960b, 1961; Khidir, 1983a; Bebawi and

Farah, 1981a). These practices all reduced the Striga seed population in the soil. However, the ability of the plant to produce large numbers of seeds that may remain viable in the soil for up to 20 years and the germination behaviour of the seeds, render these methods less effective (Andrews, 1946, 1947; Parker, 1965; Doggett, 1984; Ogborne, 1983). Therefore the benefits are gradual and cumulative and efforts have to be sustained over several years. These limitations, coupled with lack of immediate returns, hinder the adoption of these practices.

Fertilizers

It has been traditional knowledge that Striga infestation is more severe on infertile soil and that application of organic manure to infested land reduces the emergence of Striga and increases crop yield (Thomas, 1943; Ogborne, 1983). Moreover, well grown sorghum resisted infestation and supported less Striga than a poorly grown crop (Last, 1960a). Early work indicated that high rates of nitrogen applied as $(NH_4)_2SO_4$ or urea delayed emergence, caused stunting of emerged shoots and reduced flowering and dry matter production of Striga (Crowther, 1942; Last, 1960a; Agabawi and Younis, 1965). However, the effectiveness of nitrogen fertilizers was found to be dependent on existing soil fertility, application time and crop variety (Last, 1961). This is in line with the recent finding that there was no consistent evidence to indicate that host response to N-fertilization would invariably depress Striga infestation (Bebawi, 1981).

Herbicides

A large number of herbicides have been tested in the Sudan and elsewhere for the control of Striga (Hamdoun and Babiker, 1978; Ramaiah and Parker, 1982). However, it has proved to be difficult to find a good selective herbicide for prevention of Striga attack (Ramaiah and Parker, 1982). Early work at the Gezira Research Station demonstrated that application of 2,4-D and MCPA 2 - 3 weeks after sowing sorghum delayed emergence of Striga, retarded the rate of new infestation and increased sorghum yield (Wilson-Jones, 1952; Last, 1960a, 1961). However, the efficacy of these compounds appeared to depend on soil moisture and the timing of application and their performance was more reliable under irrigation than under rain-fed conditions (Wilson-Jones, 1953c; Hamdoun and Babiker, 1978). Moreover, these herbicides could be toxic to sorghum and devastating to adjacent sensitive crops (Hamdoun and Babiker, 1978).

Pre-emergence and post-emergence applications of atrazine at high rates were toxic to Striga. On the other hand, low rates were ineffective (Hamdoun, 1969; Bebawi and Farah, 1981b). Pre-emergence application of bifenox and mixtures of terbutryne and terbuthylazine were ineffective, while oxyfluorfen as an early post-emergence directed spray was toxic to Striga. Although atrazine and oxyfluorfen do not alleviate much of the damage caused by the parasite, they do prevent seed formation.

Herbicide and fertilizer combinations

Early work at the Gezira Research Station demonstrated that a combination of 2,4-D and a nitrogenous fertilizer $(NH_4)_2SO_4$ or urea was far more effective in suppressing Striga and increasing sorghum yield than sole treatments of either nitrogen or herbicide (Last, 1960a). Similar results were reported for atrazine-fertilizer combination (Bebawi and Farah, 1981b). However, recent work at Gezira demonstrated that combinations of urea with bifenox, atrazine or terbutryne + terbuthylazine were not better than fertilizer alone. On the other hand, a combination of urea and oxyfluorfen was more effective than solo treatments of either urea or oxyfluorfen.

Germination stimulants

Studies on efficacy and persistence of synthetic germination stimulants, viz, ethylene, ethephon, strigol and strigol analogues, were conducted at the Gezira Research Station (Babiker and Hamdoun, 1982, 1983). Results indicated that ethylene and ethephon were quite effective in inducing Striga seed germination under both laboratory and field conditions. Field application of ethephon decreased the number of Striga aerial shoots and increased the number of sorghum heads. Strigol and strigol analogues were very effective under laboratory conditions but were less effective in the field.

Subjection of Striga seeds to warm moist conditions for several days in the absence of stimulants was a prerequisite for effective germination. Application of ethephon, strigol and strigol analogues to unconditioned seeds did not cause any appreciable germination and in addition had an adverse effect on the responsiveness of seeds to later treatments with the stimulant (Babiker and Hamdoun, 1982, 1983). Moreover, Striga seeds were less responsive to those compounds in dry or very wet soils. Recent research results have indicated that many of the synthetic germination stimulants are unstable in soils even at moisture levels below those adequate for satisfactory induction of any phase of the germination process of Striga seeds (Babiker, Hamdoun, Rudwan, Mansi and Faki, 1987). Moreover, alkalinity and high temperature are conducive to rapid dissipation.

High cost, difficulty of application and short persistence coupled with factors such as wet dormancy, unfavourable oxygen/carbon dioxide balance, adverse effects on germination when applied prior to conditioning and the inability of Striga seeds to respond simultaneously to the pre-conditioning regimes are serious limitations for adoption of such treatments in heavy alkaline soils in the tropics.

For practical use of germination stimulants the possibility of increasing their longevity in soils by adoption of controlled-release formulation techniques should be exploited. Adoption of such techniques has been reported to slow down the degradation of many pesticides (Shasha, Trimnell and Otey, 1981).

Current work at the Gezira Research Station indicated that extracts or dried materials obtained from some plant species can stimulate germination of many Striga species and strains (Ibrahim, Babiker, Edwards and Parker, 1985).

Striga resistant varieties

Striga resistant/tolerant cultivars, should provide the simplest, the best and cheapest solution, but they take many years to develop and need to be well adapted to locality. As with resistance to many other diseases, Striga resistance is mainly associated with poor agronomic performance (Ramaiah and Parker, 1982). Many varieties have been known to be resistant to Striga but none of them has been widely adopted (Doggett, 1984). However, modern breeding methods and the availability of the world germplasm collection may improve the situation.

Three independent mechanisms of resistance to Striga were identified by Doggett (1970). These mechanisms are low stimulant production, mechanical barriers and antibiosis.

Field resistance to Striga is the combined expression of one or more of these mechanisms and possibly others. However, resistance to Striga is not just the result of interaction between host and the parasite, but also of their independent interaction, with climatic and soil factors and is complicated further by non-uniform Striga infestations and by the presence of physiological strains within Striga (Ramaiah and Parker, 1982; Khidir, 1983b).

Early work at the Gezira Research Station demonstrated that Dwarf White Milo and Mugud were less susceptible than Feterita, Dwarf Higieri and Wad Fahl (Wilson-Jones, 1953b). In recent work, both laboratory and field screening were employed to identify Striga resistant genotypes, the nature of resistance and transference of the resistance into good agronomic backgrounds (Khidir, 1983a).

Laboratory work led to identification of low stimulant producing lines in both local and exotic genotypes (Kambal and Musa, 1979; Khidir and Musa, 1981). Also, a number of cultivars were shown to have high degrees of root thickening (Khidir, 1983a). Moreover, quantitative and qualitative differences in phenolic contents between different sorghum cultivars were demonstrated (Khidir, 1983a). Resistant genotypes were found to be more frequent among the low stimulant producers and in cultivars with high phenolic content. Such characters would provide a good guide to further field studies (Khidir, 1983a).

Field work was focused on routine screening of local and exotic sorghum genotypes for *Striga* resistance and/or tolerance. Screening was carried out in *Striga*-sick plots at five locations, distributed in the Western, Central and Northern Sudan and care was taken to cover both the irrigated and rainfed sectors (Khidir, 1983a). A few field resistant entries, namely Tetron, P-967083, IS-9830 and SRN-39, were identified (Khidir, 1983a; Gebisa, 1983). Intercrossing tolerant selections has also been initiated in an endeavour to increase the levels of tolerance and attain good agronomic performance (Gebisa, 1983; Khidir, 1983a; Nour, 1985). However, current research at Gezira Research Station revealed that resistance or tolerance of most sorghum varieties breaks down at high levels of *Striga* infestation and that differential tolerance between varieties is only evident at low levels of infestation. This finding may explain the conflicting reports on resistance and susceptibility of some sorghum varieties such as SRN-39 to *Striga* and the variation in field performance of several varieties (Khidir, 1983a; El-Hiweris, 1983; Abdalla, 1986). Such a factor presents serious limitations to breeders as field variation in *Striga* infestation is quite common. In addition, *Striga* seeds could vary in their sensitivity to germination stimulants (Bebawi, 1981). We are reminded by Aberg and Stecko (1976) that plants are the product of their environment as well as their genes. Therefore, the influence of environmental variables on the ecophysiology of both sorghum and *Striga* in relation to tolerance has to be studied.

Biological control

Biological control of *Striga* is contemplated as, once established, it is self perpetuating. In the Sudan, much of the work is centred on insect pests and no work has been done on microorganisms as agents of biological control. Field surveys in 5 localities revealed the presence of 13 insect species associated with *Striga*. Of these species, the weevil *Smicronyx umbrinus* and the butterfly *Junonia orithya* are the most dominant (Khidir, 1983b).

S. umbrinus is the most promising species, as heavy infestations (33 - 100%) were reported from many localities (Ahmed, 1985). The larvae of this insect exert an appreciable pressure on *Striga* through seed elimination. They have a specific feeding behaviour which is confined only to capsules. Infected capsules are transformed into galls (Bashir and Musselman, 1984). The insect makes its greatest damage early in the season (Ahmed, 1985). Accordingly, a considerable proportion of late emerging *Striga* may be allowed to set seeds.

J. orithya larvae feed on tender stems, leaves, buds and flowers and thus can cause some reduction in the potential seed production. However, *Striga* infestation by this insect is limited. In general, only 10 - 15 larvae were reported per 100 plants (Baahir and Musselman, 1984; Ahmed, 1985).

S. umbrinus and *J. orithya* are attacked by some parasites which tend to reduce their populations in the field. The larvae of the first species are attacked by the pteromalid wasp *Pteromalus semotus* while those of *J. orithya* were attacked by the tachinid fly *Sturmia inconspicua* (Khidir, 1983b). These parasites reduce the efficiency of these insects if they are to be used for biocontrol of *Striga*. Accordingly steps have to be taken to reduce the role of these hyperparasites, perhaps through selective chemical control.

Conclusions

Appreciable research has been conducted in the Sudan on the biology, ecology and control of *S. hermonthica* during the last four decades. The results indicate that tolerant sorghum cultivars, cultural practices including rotations and nitrogen fertilization and the use of herbicides and ethylene could provide satisfactory control if sustained for several years. However, lack of immediate returns to the farmer coupled with an ill-defined policy on sorghum and millet production, annual price fluctuations, scarcity and high cost of inputs as well as absence of extension services impede adoption of the research findings. Embarkation on an effective control strategy warrants government provision of inputs at reasonable prices. Moreover, extension has to be strengthened and better facilities have to be made available to *Striga* research.

Sudan Government resources are inadequate to curtail the ever-increasing *Striga* problem as new sites are being continuously infested. The distribution of the parasite in the various ecological zones makes the adoption of strict quarantine measures rather impossible. International assistance to implement research findings and strengthen research capabilities to improve on the present control strategy are deemed necessary. Moreover, the enormous wealth of information and experience in the developed countries have to be made available to developing countries like the Sudan and strong connections and cooperation between scientists working on *Striga* have to be established and maintained. Adoption and transfer of new technologies can only be achieved through training of extension personnel and equipping them with the necessary facilities.

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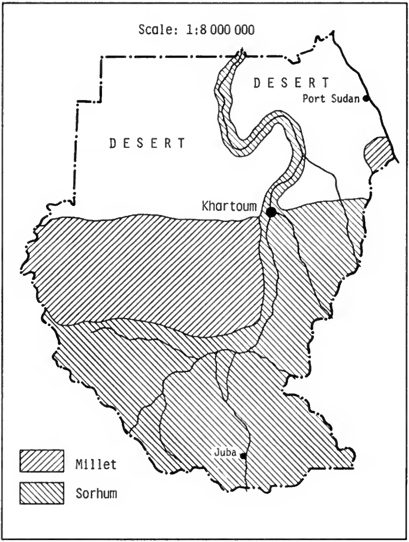
Fig. 1. Map showing the sorghum and millet producing areas in Sudan



STRIGA IN TOGO

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BACKGROUND INFORMATION ON AGRICULTURE IN TOGO

Togo covers an area of about 56 600 km^2. It is bounded to the north by Burkina Faso, to the south by the Atlantic Ocean, to the east by Benin and to the west by Ghana.

In spite of its relatively small area, Togo has very diversified climatic conditions, namely, one dry season and one rainy season in the north and two dry seasons and two rainy seasons in the south. The annual rainfall in the north ranges from 1 000 to 1 300 mm and in the south from 1 100 to 1 600 mm.

Agriculture occupies an important place in the economy of the country and accounts for 30% of the gross national product and about 30% of export earnings. Nearly 82% of the working population lives on revenue from this primary sector.

MAIN FOOD CROPS

Maize, sorghum, rice, millet, cassava, yams, beans and groundnuts are the main food crops.

The present production of the staple commodities barely meets the needs of the country. However, a disturbing fall in food production due to unreliable climatic conditions was recorded during the 1982 and 1983 cropping seasons.

CASH CROPS

The main export crops include coffee, cocoa, cotton, palm oil, coconut products, kapok and shea nuts.

Coffee and cocoa production has fallen due to the ageing of the farms. As for cotton, production is rising steadily because of the use of such products as fertilizers and pesticides.

THE *STRIGA* PROBLEM

Maize and sorghum are the basic foodstuffs of the inhabitants of the north and south of Togo (see Table 1). Consequently, these two crops are of great economic and social importance.

The low production and yields of these two crops which, for the last five years, have stood at an average of 0.87 tons/ha for maize and 0.58 tons/ha for sorghum, are often attributed to major ills classified under adverse climatic conditions. Those abiotic phenomena, however, mask the effects of one of the greatest crop parasites, *Striga*. It infests maize and sorghum particularly in times of drought but also when there is rainfall.

In Togo, *Striga* causes considerable damage estimated at 30 - 90% and sometimes 100%. The most infested areas are the Maritime regions, especially Lac, Vo and Yoto, districts which cover an area of about 100 000 ha used for maize production. The red-flowered *Striga asiatica* is the main parasite in these areas. In the northern regions of the country, Central Region, Kara and Savanna, where sorghum production also occupies about 100 000 ha, *S. hermonthica* is the most common parasite.

In Togo, *Striga* often appears on infertile or degraded land on which a single crop has been farmed for several years. The above-mentioned infested areas are also of very high population density, viz, $300/km^2$ in the south-east and $42 - 100/km^2$ in the Kara Region. In the Central Region, where land is more available, farmers abandon *Striga*-infested fields and clear new and more fertile areas.

STRIGA CONTROL MEASURES

The only methods used by all farmers are repeated weeding and the abandonment of severely infested fields. However, following the findings of the research conducted by IRAT, SOTOCO is popularising cotton-maize-groundnut rotation among the farmers receiving its assistance. The Sotouboua Seed Centre in the Central Region practises on its seed production farm the rotation of groundnuts, cowpeas, soybeans, maize and sorghum as a means of reducing *Striga* infestation.

EXTENSION, TRAINING AND RESEARCH ON *STRIGA*

There is an urgent need to inform and train both extension workers and farmers, considering that SOTOCO does not provide guidance to all farmers. In Togo, *Striga* research is still in the initial stages. While the results of *Striga* research are being disseminated, it is necessary to prepare other *Striga* research programmes which will lead to the formulation of *Striga* control methodologies at the national level.

INTERNATIONAL ASSISTANCE

There has been no international assistance for Striga control. Efforts in this area are limited to crop rotation as mentioned above.

There is a need for international assistance in order to train farmers and extension workers, to set up guidance and development structures and to prepare a research programme designed to collect data which could consolidate a large-scale control methodology for weeds in general and Striga in particular.

LEGISLATION FOR STRIGA CONTROL

Considering that Striga research in Togo is in its initial stages, there are no regulations in this area. We hope that regional regulations will be formulated in order to curb infestation by this parasite and protect areas that are not yet infested. For the moment, intensification of quarantine in each country is an absolute necessity.

FUTURE STRATEGIES

A glance at Striga distribution in our sub-region reveals that this parasite has spared no country. We hope that a project covering all countries of the sub-region will be prepared in order to improve the understanding of the problem and promote controls efforts and the exchange of information concerning parasitic weeds in general and Striga in particular.

As a result, the countries without data on Striga and other weeds will be able to benefit from the experience of other countries. The headquarters of this project, which Togo has proposed to host, will coordinate the execution of national research programmes.

In Togo, future research will be based on the following :

the use of trap crops such as cotton, soybean and bambara groundnuts;

control of Striga alone and in association with other weeds;

control of Striga using various agricultural techniques including crop rotation which is already popular;

control of _Striga_ by means of the selection and dissemination of resistance varieties;

the influence of _Striga_ infestation on crop yields;

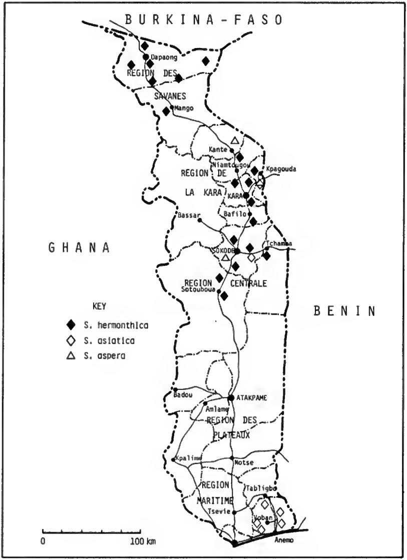
the relation between soil conditions and _Striga_ infestation.

The training of extension workers and farmers in the problems of parasitic weeds will also be carried out.

Table 1. Area (hectares) and Production (tons) of Principal Food Crops in Togo from 1979 to 1985

Crops		1979	1980	1981	1982	1983	1984	1985
Maize	Area	136 900	150 300	152 800	175 200	216 200	238 600	200 400
	Prod	159 308	138 391	150 970	150 929	144 663	221 756	181 576
Sorghum/ Millet	Area	234 500	251 000	248 000	240 300	258 000	285 500	264 000
	Prod	136 278	137 529	120 356	136 027	130 756	195 240	168 883
Paddy rice	Area	18 300	18 400	18 100	28 400	21 700	21 100	21 700
	Prod	14 642	14 700	14 512	16 304	10 033	17 760	15 185
Haricot bean	Area	84 500	89 500	87 900	97 500	106 100	123 800	116 100
	Prod	16 616	15 081	19 828	26 500	20 643	32 971	26 558
Groundnut	Area	51 300	60 000	61 900	39 100	42 100	51 300	62 300
	Prod	24 122	24 488	27 641	17 611	15 916	23 080	31 486
Cassava	Area	45 500	39 500	43 100	108 700	97 900	79 600	61 900
	Prod	432 535	407 858	372 078	366 874	345 172	444 407	474 365
Yam	Area	54 100	55 900	58 300	69 000	55 800	32 300	33 500
	Prod	482 872	483 901	527 815	471 545	383 087	341 926	364 437

Map of Togo showing the distribution of *Striga* species



PART IV

TECHNICAL SESSION

RESEARCH AND DEVELOPMENT OF STRATEGIES FOR THE CONTROL OF STRIGA HERMONTHICA IN THE GAMBIA

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SUMMARY

Surveys carried out in 1984 and 1985 established that *Striga hermonthica* was widespread, severely infesting sorghum, millet and maize. Estimated crop losses caused by the parasite ranged from 20 to 35% in cereals in most parts of the country. Results of two seasons of research culminated in the development of tentative control packages for *Striga* in sorghum and millet. The package for sorghum includes the use of a tolerant variety, ICSV 1002, side dressing of urea at 30 kg N/ha four weeks after sowing, spot spraying of emerged shoots with contact herbicide using a handsprayer and tethering of cattle in fields at night where available. The package for millet involves strip cropping, side dressing of urea at 30 kg N/ha four weeks after sowing, spot spraying of shoots with contact herbicide and tethering of cattle in fields at night where available.

INTRODUCTION

The genus *Striga* has about 30 species of which 23 species are known to occur in Africa alone. Four species have so far been recorded in the Gambia, namely, *S. hermonthica*, *S. aspera*, *S. gesnerioides* and *S. asiatica*. *S. asiatica* has not been observed in recent years while *S. gesnerioides* was only seen parasitising a wild legume, *Indigofera prieureana*. Dense patches of *S. aspera* were seen for the first time in 1985 in maize fields at the Sapu Agricultural Station. Before this, the only known cases of parasitism were on wild grasses like *Aristida kerstingii* and *Digitaria* spp. growing on eroded and heavily disturbed soils, and *Digitaria exilis* (fonio).

S. hermonthica is indisputably the most important weed species of the entire genus in the Gambia where it attacks millet, sorghum, maize and upland rice. It is a survival species and highly dependent on and adapted to traditional cultural practices.

Control of *S. hermonthica* was consequently rated as a priority area of research in the weed management programme of the Integrated Pest Management (IPM) Project with the aim of developing control measures for small-scale holdings. The research strategy adopted to achieve this aim had the following sequence of events:

(a) Survey of distribution of Striga in the main cereal crops throughout the country.

(b) Assessment of crop losses caused by Striga.

(c) Identification and testing of control practices which are technically feasible and can be compatibly combined into a package.

(d) Establishment of pilot demonstration plots at district level incorporating proven control practices.

(e) Development of a national extension programme on Striga control.

Events (a) and (b) were accomplished in 1984 and 1985. Event (c) was due to cover the 1985 and 1986 seasons. Event (d) was started in 1986 and was to be repeated in 1987. Event (e) was to begin in 1987.

RESULTS AND OBSERVATIONS

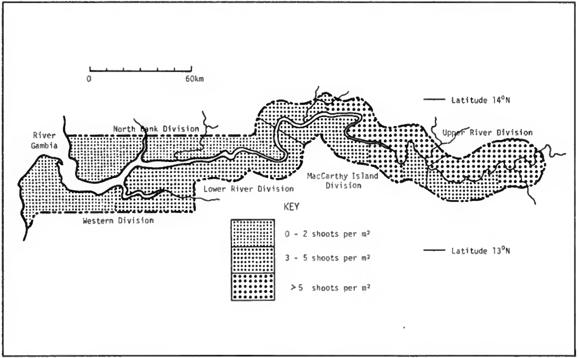
(a) Survey of distribution of Striga in the main cereal crops throughout the country.

The objectives of the survey were to highlight and publicise the fact that Striga may be the most important weed and to identify cropping systems influencing its distribution and which could be used in developing control practices.

The first survey was carried out in 1984 and the details were presented at the first OAU/FAO Workshop on Striga held in Yaounde, Cameroun in 1985 (Carson, 1985). A map of the Gambia showing the distribution of mainly S. hermonthica is presented in Fig. 1. The salient points of the survey were that nearly 75% of the fields surveyed were infested at an average of 1 - 2 shoots per m^2. The worst infested areas were the north bank portions of the Upper River (URD) and MacCarthy Island (MID) divisions. Maize was least attacked followed by early millet, late millet and sorghum in order of increasing attack. The best traditional cropping system in terms of reducing Striga populations was to rotate early millet and groundnuts over a single season and to allow cattle to graze the cereal stubble, tethered in the fields at night during the offseason. Neither the use of inorganic fertilizers nor intercropping of millet and groundnuts on separate rows appeared to affect Striga populations.

A follow-up survey was carried out in 1985 in three divisions to validate the 1984 results. Ten villages were selected in each division and five cereal fields were surveyed per village. The results showed again that the North Bank Division was the least

Fig. 1. Map of the Gambia showing the distribution of mainly *Striga hermonthica*.



infested area with a mean rate of 2.1 shoots per m^2. The Lower River Division had an infestation rate of 3.8 shoots per m^2 while the north bank portion of MID still showed heavy infestation of 14 shoots per m^2.

(b) Assessment of crop losses caused by Striga.

The next task after establishing the spatial distribution of Striga was to estimate crop losses caused by Striga. There were predictable problems in employing experimental designs used in general weed competition studies to estimate crop losses caused by Striga. First it was difficult to establish Striga-free plots for comparisons and secondly it was difficult to estimate losses caused before Striga had emerged above the soil.

The approach in 1984 was to subject three exotic varieties and a local variety of sorghum to three weeding regimes, viz, not weeding, control of all weeds except Striga and total weed control. The trial was established at Sapu and the results are shown in Table 1.

Table 1. Percentage crop losses caused by Striga and general weed competition in sorghum at Sapu in 1984.

		Weeding Treatment		
Varieties	No. of weeds	Only Striga present	All weeds present	Varietal means
ICSV 1001	1815	1777 (2%)*	1291 (29%)	1627
ICSV 1002	1698	1532 (8%)	436 (74%)	1222
ICSV 1006	1207	1465 (0%)	1174 (3%)	1282
Local/Samba Jabo	1165	932 (20%)	1026 (12%)	1041
Means	1471	1426 (8%)	982 (12%)	

* ( ) = %crop loss based on grain yield per unit area.

Uncontrolled Striga caused 20% crop loss in the local Samba Jabo and an overall mean loss of 8% in the varieties together.

In 1985, two trials were established at Sapu (MID) and at Samba Kunda (URD). The same varieties were assessed on their relative tolerance to Striga by comparing panicle yields of attacked plant hills with those of non-attacked neighbouring hills in each variety.

Three batches of hills, 50 sorghum hills per batch, with newly emerged Striga shoots, were labelled at 0, 2 and 4 weeks from the time Striga was seen to emerge in the field in each plot.

At harvest, three other batches of non-attacked sorghum hills were selected in close proximity to their labelled and attacked counterparts. The idea was that each time a Striga-attacked hill was harvested, a neighbouring or nearest non-attacked hill in similar edaphic conditions was also harvested so that their respective panicle weights could be compared. Percentage crop losses or otherwise were estimated on the basis of the difference between the means of panicle weight of non-attacked and those of neighbouring attacked hills at each of the three periods of Striga emergence. The results are shown in Table 2.

Table 2. Panicle weight of four varieties of sorghum as influenced by Striga and the time of its emergence at Sapu, 1985.

	% Panicle weight loss caused by Striga				
Varieties	Early emerging (week 0)	Medium emerging (week 2)	Late emerging (week 4)	Variety mean	Grain yield kg/ha
Local	44 (41.6)*	40 (39.2)	21 (27.3)	36 (27.3)	913
ICSV 1001	24 (29.3)	12 (20.3)	3 (10.0)	13 (21.1)	1623
ICSV 1002	32 (34.4)	18 (25.1)	6 (14.2)	19 (25.8)	1287
ICSV 1006	51 (45.6)	29 (32.6)	14 (22.0)	31 (33.8)	1160
Means	38 (38.1)	25 (30.0)	11 (19.4)	24	
LSD 5%		(7.0)		NS	

*( ) = transformed percentage figure.

The mean crop figure of all the varieities was 24%. The local Sambo Jabo experienced the highest loss of 35% while ICSV 1001 had the least loss of 13%. The time of emergence of Striga had a profound effect on the extent of crop loss. Early emerged Striga shoots were more damaging than the medium and late-emerging shoots.

Infestation by Striga at the site was very severe. Almost all the hills of the local variety were attacked and this ruled out any meaningful assessment of crop loss on hill basis in this variety. In the other varieties, crop loss ranged from 25 to 37% with an overall mean of 30%. Early emerging shoots caused more damage than the medium and late emerging shoots.

Crop loss caused by Striga was estimated to be 20% when expressed on unit area basis in the widely cultivated local Samba Jabo variety at Sapu in 1984. At the same site in 1985, the comparative figure derived on a per hill basis was 35%.

Results of the trial at Samba Kunda are shown in Table 3.

Table 3. Panicle weight of four varieties of sorghum as influenced by Striga and the time of its emergence at Samba Kunda, 1985.

	% Panicle weight loss caused by Striga				
Varieties	Early emerging (week 0)	Medium emerging (week 2)	Late emerging (week 4)	Variety mean	Grain yield kg/ha
Local	--	--	--	--	1150
ICSV 1001	48	37	26	37	855
ICSV 1002	54	16	5	25	1662
ICSV 1006	33	30	26	30	1392
Means	45	28	19	30	

Variation in the two estimates was most probably due to differences in the methods employed in their determination. On the one hand, the 20% loss obtained on unit area basis was actually a measure of the damage caused by competition of the above-ground Striga shoots and therefore was, at best, only a partial estimate. This is because the control plots were not Striga-free and some losses could occur even before Striga shoots had emerged above the soil.

On the other hand, the 35% crop loss derived on a per plant basis, although a true reflection of the damage caused by both below- and above-ground competition of Striga, could be an over-estimation if it were extrapolated to unit area. The reason is that infestation is rarely total and uniform in a crop.

An approximation of crop loss then was likely to lie between the 20 and 35% limits, which is quite acceptable for Sapu area with a natural infestation of 3 - 5 shoots per m^2.

True crop loss, however, can be expressed as a function of crop loss on a per hill basis and percentage of infested hills in the field. Thus

true crop loss = % crop loss x % infested hills in the field.

For example, given that % crop loss on a per hill basis at Sapu was 35% in a field where 80% of the hills were infested, then

$$\text{true crop loss} = \frac{35 \times 80}{100} = 28\%$$

(c) Control measures.

There are several suggestions for controlling Striga but unfortunately only a few seem to be technically feasible and cost-effective in small-scale holdings. The long list of suggested control measures include the use of resistant varieties, hand-pulling, chemical control, high rates of inorganic and organic nitrogen fertilizers, crop rotation, trap cropping, catch cropping, the use of germination stimulants and biological control.

What was done in the IPM programme was to test some of the promising and easy-to-accomplish measures in pre-extension demonstration trials in farmers' fields. Those which worked would be combined in a package to be demonstrated on a pilot scale in farmers fields. The selected control measures tested were as follows:

1. Resistant varieties.

Sorghum. Varietal resistance seems to be the most feasible and economic means of controlling Striga. ICRISAT has been engaged on the problem since 1975 and has developed sorghum varieties with broad spectrum stable resistance. Although these varieties were well adapted to conditions of their origin in Burkina Faso, there were some doubts whether they could demonstrate the same degree of tolerance under Gambian conditions. One of the objectives of the trials on crop loss assessment presented in Tables 1, 2 and 3 was to compare the relative tolerance of the sorghum varieties ICSV 1001, ICSV 1002 and ICSV 1006 and Sambo Jabo to Striga.

The results in Table 1 show that all the exotic varieties are relatively more tolerant to Striga. ICSV 1006 experienced 0% crop loss while ICSV 1001 and ICSV 1002 experienced 2% and 8% crop losses, respectively. In the second trial at Sapu in 1985, ICSV 1001 was the most tolerant variety, exhibiting 13% loss in panicle yield (Table 2). This was followed by ICSV 1002, ICSV 1006 and the local variety in order of decreasing tolerance to Striga. Grain yield was highly correlated with the order of tolerance to Striga.

In the trial at Samba Kunda in 1985 (Table 3), ICSV 1002 was the best of all varieties in terms of both tolerance and panicle yield. However, none of the varieties could be regarded as highly tolerant when judged by the number of attacked hills, panicle yield and growth performance.

On the whole, ICSV 1001 exhibited a high level of tolerance and yielding ability at Sapu where infestation of Striga was mild. The same variety, however, performed poorly in the severely infested soils at Samba Kunda. In contrast, ICSV 1002 was more consistent in the degree of tolerance at the two sites. It could mean either that ICSV

1001 may not have a broad spectrum resistance, which presupposes the existence of different ecotypes of Striga at the two sites, or that there is a density threshold above which the reistance of ICSV 1001 breaks down.

ICSV 1002 was put forward as a recommendation because of its stable resistance to Striga, grain qualities and tolerance to insects like Dysdercus superstitiosus and Heliothis armigera which have the potential of becoming important pests on sorghum (Sankung, 1985).

Millet. There has not been a parallel breakthrough in developing resistant varieties of millet as was the case in the sorghum programme. The current ICRISAT recommendation 3/4 HK, was observed to have failed to set seeds at some of the test sites in the 1985 Millet Improvement Programme of CILSS and this ruled out further consideration.

Maize. Some 14 early maturing streak-resistant lines from IITA were grown together with two local varieties NCB and JEKA in a randomised complete block design with four replications. Nearly 40% of the hills of NCB and JEKA were attacked by Striga while two entries, TZESR-W, ILON, 82 and TZESR-M.G.-82 were free of attack. These two entries are being evaluated again in the 1986 season.

2. Manual and chemical control of Striga in early millet and sorghum.

Three long term pre-extension trials were established in farmers fields of early millet at Kuntaur (MID), Sapu (MID) and Karantaba (LRD) during the 1985 season. The objective was to demonstrate the long term benefit of preventing Striga shoots from setting seed by hand-pulling and chemical control. Hand-pulling was carried out at three growth stages of the crop, viz, flowering, grain maturity and 2 weeks after crop removal. Chemical control was achieved by spot spraying Striga shoots with a 2% solution of paraquat using a small handsprayer at the same crop stages as hand-pulling.

The results at Kuntaur are shown in Table 4 and the partial budget of the control measures is shown in Table 5.

Striga infestation was very severe at Kuntaur with more than 41 shoots per m^2. Both hand-pulling and chemical control reduced Striga populations effectively and improved grain yields significantly. Chemical control increased income by over D60.00 while hand-pulling was not cost-effective because of the high labour cost (see Table 5).

The results of the trial at Sapu are shown in Table 6.

Table 4. Economic evaluation of hand-pulling and chemical control of *Striga* in early millet at Kuntaur, 1985.

Treatment	Results at harvest Grain yield (kg/ha)	*Striga* shoots ($No./10m^2$)	% Yield increase*	Incremental income dalasis/ha
Farmer practice	91	417	--	--
Hand-pulling	230	40	153	-184.83
Spot spraying	291	7	219	69.50
LSD (5%)	86	--	--	--

* Compared with farmer practice.

Table 5. Partial budget for methods of control at Kuntaur.

Extra cost, dalasis/ha		Grains, dalasis/ha	
Spot spraying paraquat 2% soln			
Gramoxone IL @ D18/litre	18.00	Revenue from extra 200 kg @ D0.70/kg	140.00
10% depreciation on handsprayer (cost: D20)	2.00		
Labour of 3 man-days @ D5.50/day	16.50		
Cost of harvesting extra 200 kg @ D0.17/kg	34.00		
Total extra cost	D70.50	Net gain	D69.50
Hand-pulling			
Labour of 47 man-days @ D5.50/day	258.50	Revenue from extra 139 kg @ D0.70/kg	97.30
Cost of harvesting extra 139 kg @ D0.17/kg	23.63		
Total extra cost	D282.13	Net loss	D184.83

Infestation of *Striga* at Sapu was less severe and control was more timely. Grain yield was increased by 23% with the chemical treament and by 4% with hand-pulling. The difference in yield between the two treatments was not significant although chemical control increased income by D95.43 while the outlay on hand-pulling far exceeded the income from extra grain.

Table 6. Economic evaluation of chemical control and hand-pulling of Striga in early millet at Sapu, 1985.

	Results at harvest			Incremental
Treatment	Grain yield (kg/ha)	Striga shoots (No./10m²)	% Yield increase*	income dalasis/ha
Farmer practice	1 068	38	--	--
Hand-pulling	1 109	15	4	-126.27
Spot spraying	1 315	3	23	95.43
LSD (5%)	NS	--	--	--

* Compared with farmer practice.

Results of the trial at Karantaba (see Table 7) showed that chemical control increased yield by 33% over farmers' normal practice and also increased income by D125.00.

Table 7. Economic evaluation of chemical control and hand-pulling of Striga in early millet at Karantaba, 1985.

	Results at harvest			Incremental
Treatment	Grain yield (kg/ha)	Striga shoots (No./10m²)	% Yield increase*	income dalasis/ha
Farmer practice	916	45	--	--
Hand-pulling	1 021	28	12	-92.32
Spot spraying	1 221	1	33	125.00
LSD (5%)	NS	--	--	--

* Compared with farmer practice.

Hand-pulling increased grain yield by 12% but depressed income by over D92.00.

Flowering of early millet invariably coincided with the emergence of Striga shoots. Hence it was important to destroy the shoots within the shortest possible time in order to arrest the heavy drain on photosynthates meant for grain filling. Spot spraying of shoots with paraquat destroyed them within a matter of hours and the spray could reach those shoots that had emerged between the tillers of the crop and were inaccessible to hand-pulling. There was no regrowth from the spot sprayed shoots of Striga. Labour input for hand-pulling was such that control would always be protracted and expensive.

Sorghum. Two trials were established at Kayoum Bintang in the Western Division and at Sapu in the MacCarthy Island Division. The objectives were the same as those of the early millet trial. 2,4-D was included as a second chemical treatment because of its safety and low cost.

The results of the trial at Kayoum Bintang are shown in Table 8.

Table 8. Economic evaluation of hand-pulling and chemical control of *Striga* at Kayoum Bintang, 1985.

Treatment	Results at harvest Grain yield (kg/ha)	 *Striga* shoots (No./10m^2)	% Yield increase*	Incremental income dalasis/ha
Farmer practice	188	39	--	--
Hand-pulling	203	11	8	-141.00
Spot spraying				
2,4-D 2% soln.	220	6	17	-12.00
paraquat 2% soln.	263	4	40	1.00
LSD (5%)	NS	--	--	--

* Compared with farmer practice.

Yields from the trial were poor because of the prevailing poor husbandry practices. Paraquat was the more effective treatment, increasing yield by 40%. 2,4-D increased yield by 12% and was relatively better than hand-pulling which reduced income because of the high labour requirement.

The results of the trial at Sapu are shown in Table 9.

Table 9. Economic evaluation of chemical control and hand-pulling of *Striga* in late sorghum at Sapu, 1985.

Treatment	Results at harvest Grain yield (kg/ha)	 *Striga* shoots (No./10m^2)	% Yield increase*	Incremental income dalasis/ha
Farmer practice	1 242	36	--	--
Hand-pulling	1 748	15	41	104.50
Spot spraying				
2,4-D 2% soln.	1 638	12	32	170.00
Paraquat 2%	1 890	5	52	287.50
LSD (5%)	503	--	--	--

Both hand-pulling and paraquat produced yields which were significantly greater than the farmers' normal practice. Yield was increased by 52% in the paraquat treatment, bringing in D287.50 extra income. Hand-pulling produced more yield than 2,4-D but it gave less incremental income because of the high labour input.

In conclusion, it can be said that although 2,4-D waa much cheaper and less toxic than paraquat, it was slower in action taking several days to effect a complete kill of the shoots. This meant that there was further damage to the crop even after spraying. Regrowth of shoots also occurred in some instances. Hand-pulling was labour intensive and it was difficult to pull out young shoots without breaking them. Paraquat was very effective and quick-acting and killed the shoots without stimulating regrowth.

The only problem with the use of paraquat is its toxicity. There are plans to replace it with safer products such as glyphosate, glyphosate + 2,4-D mixture or paraquat based mixtures such as paracol and gramuron.

3. Cropping systems: intercropping and strip cropping

Intercropping. Germination of Striga is known to be temperature-dependent with 30° C as the minimum threshold and 35° C as the optimum. As such, provision of shade at the bases of the host crop might lower soil temperatures and posaibly reduce germination and emergence of Striga. Several agronomic possibilities exist for influencing soil temperatures. Those that appear to be technically feasible in small-holdings are mulching, intercropping and high density sowing. While it may be inappropriate to recommend mulching because farmers use crop residue for fencing and as animal feed, some farmers practise intercropping of sorghum with groundnuts. However, the two crops are usually sown pure in different rows in a ratio of 10 groundnut rows to one cereal row. In this type of spatial arrangement, there is no chance of the legume shading the bases of the cereal crop. If however, the legume were to be intercropped with the cereal within the rows, then there is bound to be shading of the bases of the cereal plants which are also close enough to form an early and close canopy to provide further shading of soil surface.

A trial was established at Sapu in 1985 to investigate the effect of within the row and between the row intercropping of sorghum and groundnuts on soil temperatures and emergence of Striga. The treatments were sole sorghum, sole groundnuts, sorghum intercropped with groundnuts in alternate rows and sorghum intercropped with groundnuts within rows. Soil thermometers were positioned randomly at the midpoint between any two adjacent sorghum plants within the row to monitor diurnal soil temperatures at depths of 10, 15 and 20 cm.

Striga shoot count was significantly higher in sole sorghum than within-row intercropping (see Table 10).

It must be noted that in spite of the fact that Striga numbers in between-row intercropping were determined in 3 rows instead of 5 rows as the case in the others, the score was not significantly different from that of sole sorghum. Cumulative yields of intercropping exceeded yields of sole cropping thus under-scoring the relative advantage of intercropping.

Table 10. Striga shoot numbers and grain yield of sorghum and groundnuts in intercropping studies at Sapu, 1985.

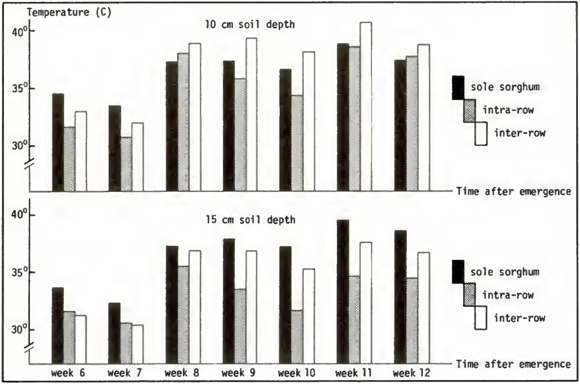
Treatment	Panicle yield of sorghum (kg/ha)	Pod yield of groundnuts (kg/ha)	Striga shoots (No./75 m²)
Sole sorghum	3 231	--	88 (9.4)*
Sole groundnuts	--	2 310	0 (0.7)
Sorghum + groundnuts in alternating rows	3 028	935	45 (6.7)
Sorghum + groundnuts alternating within rows	1 775	1 794	26 (5.1)
LSD (5%)			(3.8)

*( ) = transformed / x + 0.5

Mean weekly soil temperatures at depths of 10 and 15 cm are presented in Fig. 2. Temperature data at a depth of 20 cm were omitted because there was not much variation between treatments. Variation in soil temperature was more pronounced at 15 cm depths with sole sorghum giving the highest temperature, followed by between-row and then within-row intercropping, in that order. Soil temperatures at 10 cm depth in the 6th and 7th weeks were at least 2°C lower and closer to the minimum threshold in the within-row treatment than in sole sorghum. This period was found to coincide with the peak period of germination and attachment of Striga to host from excavations of millet plants by a visiting team of Striga experts. Most probably it was the relatively low soil temperature in the within-row intercropping at this stage which reduced germination and decreased the emergence of Striga.

There was the possibility that the trap-cropping effect of groundnuts could also have curtailed the emergence of Striga. To resolve this, the trial was expanded in 1986 to include a treatment with straw mulch so as to separate temperature and trap cropping effects.

Fig. 2. Weekly mean soil temperatures under sole cropping and intra- and inter-row intercropping at 10 cm and 15 cm soil depths.



In spite of demonstrated yield advantage and favourable effect on Striga attack, there will be technical constraints against adopting within-row intercropping in the draft animal based cropping systems of the Gambia. For one thing, within-row intercropping is not amenable to animal draft seeding and harvesting. The other problem is that different packages of fertilizer and pest management will have to be worked out for this type of intercropping.

Influence of type of legume on emergence of Striga in between-row intercropping of maize.

The object of this trial was to compare the effect of cowpeas, groundnuts and bambara groundnuts as intercrops on the emergence of Striga shoots in the companion maize crop. The trial was of mixed factorial design and was carried out by the maize agronomist. Maize and the particular legume were intercropped on alternate rows. Striga shoots were counted prior to harvesting maize. Table 11 shows the results of the Striga counts. There was a significant effect of type of legume on Striga population in the companion maize crop. Plots with cowpeas on alternate rows had fewer Striga shoots than those with either bambara groundnuts or groundnuts as the intercrop.

Table 11. Influence of type of legume intercrop on number of Striga shoots in companion maize crop.

Crops	No. of Striga shoots / 4.5 m^2	Transformed no. of shoots / 4.5 m^2
Maize-cowpeas	5.7	2.38
Maize-bambara groundnuts	14.5	3.82
Maize-groundnuts	33.7	5.70
LSD (5%)	-	2.68

The influence of the three legumes on Striga population might be linked with the degree of shading that each legume casts at the base of the adjoining maize row. In particular, the variety TN 88-63 of cowpea being an indeterminate type, twined around the base of the maize, casting a dense shadow which may have kept soil temperatures well below the optimum of 35°C for the germination of Striga. Bambara groundnuts did not extend vegetatively into adjoining rows but were more vigorous and therefore produced more shade than groundnuts.

These results have further endorsed the likelihood that the favourable effect of the legume intercrop in reducing emergence of Striga shoots was through shading and the consequent effect on soil temperatures.

Strip cropping of early millet. An improved weed management technique is on the point of being introduced in the draft animal based cropping of early millet. It involves no tillage whereby seed is drilled in permanent 20 cm wide bands, 90 cm apart, with minimal soil disturbance. Weeds growing within the 20 cm bands are controlled either by application of a pre-emergence herbicide at a low rate (propazine at 1 kg/ha) or early hand weeding of the 20 cm bands. Between the row, weeds are allowed to grow to a height of 20 cm (4 weeks) and then cultivated by using animal drawn tine cultivators. All emerged Striga shoots are controlled by spot spraying of a contact herbicide.

There are strong possibilities that populations of Striga could be reduced by this weed management technique for the following reasons.

1. The spot treatment of Striga shoots will prevent the return of seed to the soil. If this is repeated for several seasons, it may be possible to exhaust the soil's reservoir of Striga seed in the permanent 20 cm bands.

2. By allowing between-the-row weeds to grow, they could serve as 'trap' or 'catch' crops and thus help to deplete Striga seeds in the soil.

3. Mulch generated by cultivating the tall between-row weeds could lower soil temperatures and thereby reduce germination of Striga, improve water holding capacity of the soil and raise soil fertility.

Four trials have been established on a pilot scale at Tumane Tenda (WD), Karantaba (LRD), Kuntaur (MID) and Kerewan (NBD) in the 1986 season to demonstrate the effect of the advocated technique on Striga populations.

4. Biological control

Striga spp are short-lived annuals producing numerous tiny seeds which are easily spread and remain viable for long periods in the soil. As such, they are not perfect targets for biological control. However, because biological control is relatively cheap and environmentally safe, it still remains a viable option.

Attempts were made to survey for natural enemies of Striga in the Gambia. The most abundant insect species causing any sort of damage belong to the weevil genus Smicronyz. At Sololor Fulakunda in 1985, four 150 m rows of sorghum were randomly selected in a farmer's field. Both the total of Striga plants and insect damaged Striga plants were counted. The results are shown in Table 12.

The overall percentage of insect damaged Striga plants was 7.4% and damage in most cases was limited to a few tiny holes on leaf surfaces (see Table 12).

Table 12.

Row no.	Total Striga plants	No. of insect damaged plants	% of insect damaged plants
1	65	6	9.2
2	72	1	1.4
3	92	11	11.9
4	42	3	7.1
Mean	68	5	7.4

Second in importance were species of Junonia, a butterfly whose larvae caused considerable defoliation but were too few in numbers to produce any impact on Striga population.

(d) Establishment of pilot demonstration plots

The most promising and technically feasible techniques of controlling Striga were combined in a package which was to be tested on pilot scale in farmers' fields beginning this year. Pilot demonstration plots have been established in the Striga 'hot spot' areas in the 1986 season in both sorghum and millet fields. Results are not yet available so only the details of the packages will be given.

i) Demonstration of a package for the control of Striga in sorghum

Objective: To test a package of integrated Striga management practices for the small-scale farmer in severely infested farms.

Sites: Sololor (MID) Samba Kunda and Demba Kunda (URD)

Package: Resistant variety - ICSV 1002
Fertilizer - spot application of urea at 30 kg N/ha 4 weeks after sowing
Herbicide - spot spraying of 2% solution of paraquat at 70 days and at 50% flowering
Off season - tether cattle at night in field to provide dung

Plot size: 1 ha split to contain package and farmer practice.

ii) Demonstration of a package for the control of Striga in early millet

Objective: Same as for sorghum

Sites: Tumane Tenda (WD), Karantaba (LRD), Kuntaur (MID), Kerewan (NBD)

Package: Variety - local variety

Land preparation/weed management - zero tillage, sowing in rows; application of pre-emergence herbicide or early hand-weeding of 20 cm band; inter-row weeds allowed to grow to 20 cm high and cultivated to mulch between rows
Fertilizer - spot application of urea at 30 kg N/ha 4 weeks after sowing

Herbicide - 2% paraquat solution at 50% flowering

Off season - tether and graze cattle *in situ* to manure field

Plot size: 1 ha split to contain package and farmer practice.

The final step will be to develop a national extension programme to control *Striga*.

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RECENT RESULTS OF STRIGA INVESTIGATIONS IN THE CILSS INTEGRATED PEST MANAGEMENT PROJECT WITH SPECIAL REFERENCE TO NIGER

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INTRODUCTION

Parasitic weeds of the Scrophulariaceae seriously reduce yields of the major staple cereals, millet and sorghum, and the grain legume, cowpea, in the Sahel and neighbouring Sudan and Guinea savanna zones of Africa. Most estimates of yield loss vary from 15 to 70%. Doggart (1965) estimated yield reductions to be 1 kg/1000 *Striga* plants for sorghum in East Africa. Ramaiah (1983) reported losses of 10 to 35%, a yield reduction of 10% representing a density of *Striga* of 15 000 plants/ha. Losses may be much higher in ordinary farm crops where complete crop failure is not uncommon.

The high population growth rate in Africa and desertification of the Sahel by expansion of the Sahara increases pressure on existing arable land creating favourable conditions for *Striga* (Zehrer, 1985). The successful expansion of highly productive short season maize in Northern Nigeria, Togo, Benin and Ghana is under threat from *Striga* (Parkinson, 1985). Cowpeas too are increasingly threatened. *S. gesnerioides*, already widespread in semi-arid zones of Africa was reported by Obilana (1983) to be spreading southwards from the Sahel and Sudan savanna to the Northern Guinea savanna. Little is known of the economic importance of *Striga* in other host crops. These include sugar-cane, rice, fonio (*Digitaria exilis*), tobacco and important wild fodder species of grasses and legumes.

Striga is a member of the family Scrophulariaceae, sub-family Rhinanthoideae, being separated morphologically from other members of the Rhinanthoideae by unilocular anthers and a bilabiate corolla with a pronounced bend in the corolla tube. *Buchnera*, a closely related genus, has an almost radially symmetrical corolla and lacks a bend in the tube. Hepper (1963) has given useful descriptions for the identificiation of African Scrophulariaceae. Several recent reviews based on surveys and experimental work have been made by Musselman and others on the genus *Striga* (Musselman *et al*. 1983, 1984). An ICRISAT publication is recommended for descriptions of economically important *Striga* species.

Allogamy is well developed in S. hermonthica (Safa, 1984) which exhibits sporophytic incompatibility. Pollination is dependent on insect vectors. Inbreeding, autogamy, is well developed in S. gesnerioides. No pollen vector is needed because pollen is picked up by the elongating style. Musselman et al.(1984) showed that the barrier mechanism may be crossed between strains of S. gesnerioides.

S. hermonthica is the most economically important species in West African cereals. Evidence exists for at least two strains, one specific to millet and the other to sorghum (Wilson-Jones, 1955; Parker and Reid, 1979; Ramaiah, 1984). Millet is the principal host in the Sahel; sorghum is the principal host in the Sudan savanna zone. Parker and Reid found germination stimulants to be responsible for host selectivity. Both millet and sorghum act as hosts in the northern Guinea savanna and the transition zone between the Sahel and Sudan savanna zones (Ramaiah, 1984).

Striga control measures fall into two broad categories:

depletion of Striga seed in the soil by the use of trap crops, catch crops, germination stimulants, fumigants, etc.;

limitation or reduction of Striga seed production by removal of plants prior to seed formation, the use of herbicides and fertilizers, resistant varieties, insects, diseases and competition from intercrops and weeds.

Realism demands that recommendations for Striga control should use low input technology within the reach of the farmer and should be appreciated as worth-while by the farmer.

Striga was recognised as a major weed problem in the Sahel during conception of the USAID financed, CILSS executed Regional Integrated Pest Management Project (IPM).

The CILSS IPM Project set up a series of observation posts throughout the region to monitor and survey major pests and collect local meteorological data. Pest studies, control measures and determination of crop losses are examined by professional staff in more detail by joint regional and national programmes. Work on Striga falls into two broad categories:

varietal evaluation for Striga resistance in cooperation with plant breeding programmes;

agronomy-crop husbandry methods of weed management.

METHODS

General husbandry

Land preparation was by disc harrow, animal drawn equipment or hand hoes. Phosphate (as single super phosphate at 100 kg/ha), where used, was incorporated during land preparation. Six-row plots were used for millet and four-row plots for cowpeas. Plant station densities were 10 000/ha for millet (1 x 1 m), 44 444/ha for sorghum (0.75 x 0.3 m), and 31 250/ha for cowpeas (0.8 x 0.4 m). Crops were thinned to three plants per station for millet and sorghum and one for cowpeas. One to three hand weedings were made during the first 5 - 6 weeks of crop growth. Emphasis was placed on early weeding in the immediate vicinity of the crop. Cowpea pests were controlled by two to three applications of insecticides (deltamethrin + dimethoate or cypermethrin + carbosulfan).

Striga evaluations

Striga plants were counted and attributed to specific plant stations at intervals starting 7 to 10 days after the appearance of the first Striga plant. Data were examined in two ways. First on the proportion of stations attacked and then on the basis of Striga density.

Striga survey

At each observation post, 50 fields were chosen at random and Striga plants were counted in one metre quadrats placed round the plant stations. Evaluations were made shortly before harvest in fields selected within a month of sowing.

Striga development

Striga plants were counted in 5 fixed quadrats (3 x 3 m), at fortnightly intervals. Where appropriate, plots were enlarged to give a minimum of 75 stations per field. Development of Striga is currently being examined in relation to crop development and meteorological data over several years.

RESULTS

Striga distribution

Three species of Striga are commonly found in the rainfed agricultural zone of Niger, namely, S. hermonthica, S. aspera and S. gesnerioides. The geographical distribution from the IPM Project surveys is presented in Fig. 1.

The first *S. hermonthica* plants were observed 5 - 8 weeks after sowing. Populations increased slowly at first but rapidly as grain matured.

S. hermonthica was found on millet in most areas where the crop is cultivated south of the 14th parallel. Densities varied considerably. Densities were higher in wet years (1985 and 1986) than in a dry year (1984). Plant densities reached more than 500 000/ha in Bengou (see Table 1), causing considerable yield loss. Phytotoxic symptoms were severe at stem elongation and many plants failed to produce useable ears.

Table 1. Percentage of millet fields surveyed with *S. hermonthica* (% Fields) and maximum *Striga* population (*S. max*)

Location	% Fields	S. max
Birkin Burgi	56	16.1
Birni N'Konni	46	76.5
Kale Pate	78	192.0
Bengou	70	
Chikal	12	351.0
Ouallam	44	41.5

S. hermonthica was absent on sorghum east of Malbaza and not observed at Tahoua on a survey trip to the area (1985). Two localised heavy infestations with populations over 400 000/ha, were found on the ONAHA irrigation project near Konni resulting in virtual crop failure. Interestingly, the majority of sorghum fields on the scheme are *Striga* free. In the Konni area, many sorghum fields appeared to be moderately infested but examination showed that *Striga* was present on a millet intercrop. Approximately one third of sorghum fields examined in the Konni-Malbaza area were parasitised whereas *Striga* was present in all fields surveyed at Bengou (see Table 2).

Table 2. Number of sorghum fields surveyed and percentage with *S. hermonthica*.

Location	Fields	% Infested
Magaria-Matamèye	15	0
Garin Mskada	4	0
Bakin Birgi	8	0
Malbaza	8	4
Konni	37	12
Bengou	17	17

Emergence on sorghum occurred 2 to 3 weeks after emergence on millet in the Bengou area. This may have been due to later sowing, the heavier soil of the sorghum area or the presence of a sorghum specific Striga race.

An isolated Striga plant was found on sorghum at Diffa (1985) and three on sorghum at CNRA-Tarna in 1986.

S. gesnerioides occurred in all the areas examined south of the 14th parallel as a parasite of cowpeas. Infestations were especially high in the Zinder-Magaria-Matameye and Maradi areas. Striga was found in the majority of fields, populations were frequently greater than 25,000 plants/ha.

At 4 out of 8 observation posts, Striga was present as an intercrop in the fields surveyed. S. gesnerioides occurred in 33% of cowpea fields at Konni in contrast to 0 and 4%, respectively, for Ouallam and Chikal. The author found more than 50% of cowpea crops examined on the Niamey - Filingue road to be parasitised. This contrasts sharply with data from Chikal.

There were no cowpeas in the fields surveyed at Kale-Pate, Bakin Birji, Diffa and Niamey.

Table 3. Number of fields with cowpeas and percentage attacked by S. gesnerioides

Observation post	Number of cowpea sites	% of sites with Striga
Chikal	27	3.7
Bengou	2	100.0
Ouallam	35	0
Konni	36	33.3

Five weed species, Indigofera hirsuta, Ipomoea vagans, Merrimia tridentata, Tephrosia bracteolata and Jacquemantia tamnifolia were found as hosts to S. gesnerioides. Indigofera and Ipomoea were frequently and heavily parasitised in the Malbaza and Bazaga areas. A summary of host distribution and incidence of parasitism is given in Table 4.

Striga plants growing on Merrimia and Ipomoea tended to be more slender with less branching than those on cowpeas. However, plants of the slender morphotype were often found in weed-free cowpea stands making an examination of the weed flora essential in evaluations of S. gesnerioides. This is especially important in varietal work where different geographical Striga races produce differential host variety responses; resistant varieties could be mistakenly recorded as susceptible if an alternate weed host is present. Races tend to be host specific and rarely parasitise more than one family (Parker, personal communication).

Table 4. Location of hosts of Striga gesnerioides.

Location	Cowpea	Ipomoea	Indigof.	Merrim.	Tephro.	Jacqu.
Diffa		*				
Guidimouni	**					
Zinder	***	*				
Magaria	***					
Bande		**				
Matameye	***	*				
Tchadoua	**	*	*	*		
Maradi	***		*	**	*	*
Madarounfa	**	**	*	*		
Malbaza	**	***	***	*		
Tamske	*					
Bazaga	*	*	*	*		
Bengou	*				*	
Hamdallaye	**	*				
Damana	***	*	*			
Louma		**	*			
Gao		**	*	*		
Kolo		*				
Sadore	*			*		

The effect of ethylene application on Striga

S. hermonthica was first noted about the middle of August at both locations with populations increasing to the end of September. By the end of September, all treatments applied before the emergence of Striga reduced the Striga population by 50% or more. Surprisingly, more Striga was recorded at Tarna than at Magaria, maximum population being 30 650 and 4 500 plants/ha, respectively. Corresponding lowest populations from the best ethylene treatments were 8,000 and 1,130 plants/ha. The proportion of hills with Striga was similar for all treatments at Tarna whereas at Magaria a significant reduction from 34.5%to 18.9%was found.

Overall grain yields for the trial were 11.16 and 3.4 Q/ha; the higher yield obtained at Tarna was due to higher crop populations (8 868 compared with 5 383 hills), more spikes per hill (3.4 compared with 2.7), larger spikes (54.3 cm compared with 46.2 cm) and better shelling percentages (58.4% compared with 49.9%). Ethylene treatment had no effect on these treatments nor on grain size. The highest yielding treatment had the lowest Striga population, but the data in Table 5 show no clear relationship between the two.

The low S. hermonthica population in the Magaria trial contrasted sharply with the high plant densities found in the adjacent farmer area. Later sowing, and re-sowing later still, reduced crop vigour and delayed crop maturity, both of which may have reduced the incidence of parasitism. The final Striga evaluation was carried out 18 days before harvest which would underestimate the final Striga density. At Tarna, the Striga population almost doubled over this period.

Table 5. Influence of time of application of ethylene on grain yield of millet (Q/ha) and Striga populations ('000/ha) at Tarna and Magaria

Application dates		Grain yield		Striga population	
Tarna	Magaria	Tarna	Magaria	Tarna	Magaria
Untreated	Untreated	10.88	2.90	30.75	4.50
25/07	16/07	10.51	4.23	13.75	1.13
9/08	30/07	11.91	3.30	14.00	2.38
22/8,1/9	12/8,25/8	11.29	3.86	11.25	1.25
1/09	25/08	10.07	3.29	29.75	1.25
22/08	12/08	12.30	2.80	8.00	1.63
Mean		11.16	3.40	17.92	2.02
Coeff. of variation		18.3	40.0	83.9	79.6
F		0.68	0.66	1.70	2.61

The lack of a reduction in Striga densities by the late ethylene application can be explained by seeds capable of germination already being attached to the millet and thereby the disruption in attachment to the host caused by ethylene was no longer effective. Ungerminated Striga seed may have been in wet dormancy and therefore unresponsive to stimulation. Striga takes 2 - 4 weeks to emerge after germination accounting for the steady increase in population during the unresponsive period to ethylene.

Preliminary observations in the laboratory with seed collected at both sites showed a 22 to 26% stimulation of germination 5 months after harvest. No host was present to examine attachment.

Injection of ethylene gas reduced Striga populations in cowpeas from 99.63 to 37 thousand/ha in the warm dry season whereas injection of ethylene gas had no significant effect on either crop nor S. gesnerioides in the first rainy season. Parasitism of cowpea plants was very high at Magaria with an average parasitism rate of 97.7%.

Populations of Striga were over 100,000/ha for most treatments. Populations ranged from 10,420 to 30,000 plants/ha at Tarna (average 17,720 plants/ha) with 22 to 49% of the crop parasitised (average 37.4%). Premature death of Striga before grain maturity was unrelated to treatment and averaged 41%. Striga populations differed significantly between replicates at Tarna.

Continuation of the dry season trial in the rains of 1986 showed a marked reduction of Striga by ethylene (from 166.1 to 51 thousand/ha). Unlike in the dry season, yields were negatively correlated to Striga population.

Cultural control of S. hermonthica

All weeding treatments significantly increased crop grain yield at both Tarna and Magaria where appreciable numbers of weeds were present. No significant differences between actual weeding treatments were observed, but the lowest yields were found where all weeding ceased 35 days after sowing. Table 7 shows both yield and Striga population data for all treatments at the three sites. Weeding increased grain size, length of flowering spike, number of spikes per hill and the number of plants surviving to maturity. All weeding treatments are averaged and presented with the unweeded data for the above parameters in Table 8.

Table 7. Effect of weeding methods from 35 days after sowing on grain yields and S. hermonthica populations.

	Grain yield as Q/ha			Striga '000/ha		
Weeding treatment	Tarna	Magaria	Bengou	Tarna	Magaria	Bengou
Unweeded*	0.31	4.47	6.40	P	0.58	0.42
No further weeding	8.72	3.07	10.18	5.43	1.92	0
Hand-pull Striga	10.30	5.54	13.24	2.71	1.58	0
Hoe Striga	9.10	4.22	10.62	3.13	3.08	0
Pluck, leave Striga	10.51	4.33	12.15	4.21	1.58	0
Pull Striga 2&5 waa	9.39	3.70	10.94	2.21	1.50	0
Mean	7.89	3.89	10.59	3.54	1.71	
Coeff. of variation	23.4	30.9	42.9	58.8	71.6	
Variance ratio	21.36	1.02	1.33	1.91	2.19	

* No weeding at all; other treatments were weeded twice up to 35 days after sowing, thereafter as stated. Cultural treatments were repeated at 2 week intervals except as indicated.
waa = weeks after appearance of first Striga in the trial.

No response to weeding in the virtual absence of weeds was found at Magaria.

Early weed competition was particularly intense at Tarna where *Cenchrus biflora* germinated along with millet. Moisture stress during crop establishment was apparent in the weedy plots. A more varied weed flora at Bengou included sedges and broad-leaved weeds.

Table 8 Effect of weeding practices on millet yield parameters

	Tarna		Magaria		Bengou	
Parameter	U/T	Treated	U/T	Treated	U/T	Treated
Grain yield Q/ha	0.31	9.60	4.47	3.77	6.40	11.42
1000 grain wt g	5.21	9.49			8.79	10.21
Spike length cm	16.6	56.56	50.60	47.96	51.3	55.2
Spikes/hill	1.15	3.35	3.24	2.86	2.74	3.83
Popn. '000/ha	1.71	8.07	6.64	6.83	8.75	9.02
Shelling %		61.6	50.3	47.6	51.9	53.7

S. hermonthica populations were too low at all sites to enable a comparison of weeding methods to be made on *Striga* populations. A non-significant increase in *Striga* density was obtained by weeding.

Effect of nitrogenous fertilizer on millet and Striga under different weeding regimes

Grass weeds, in particular *Cenchrus biflorus*, dominated the unweeded areas from crop establishment to harvest at Tarna. Occasional weeds included:

Alysicarpus ovifalius
Casaia mimosoides
Cassia obtusifolia
Cleome viscosa
Commelina spp.
Corchorus tridens
Crotalaria retusa
Croton lobatus
Hibiscus asper
Ipomoea pes-trigidis
Ipomoea vagana
Merremia tridentata
Mitracarpus villosus
Mollugo sp.
Phyllanthus sp.
Sesamum radiatum
Sesbania pachycarpus
Sida urens
Tephrosia bracteolata
Tribulus terrestris
Zornia glachidiata

Competition from *Cenchrus* was so severe that few millet plants survived to harvest in unweeded areas.

Nitrogen increased grain yields for all weeding treatments but reduced yield where there had been no weeding (see Table 9). This may have been the result of increased competition from weeds more able to utilise nitrogen. A highly significant increase in spike length and number of spikes resulted from nitrogen use (see Table 10).

Weeding treatments had a dramatic effect on grain yield and crop parameters contributing to grain yield such as 1000 grain weight, spike length, number of spikes per station and stand (plants surviving to harvest). An additional overall weeding 6 weeks after sowing was no more beneficial than an earlier single overall weeding. Ring weeding increased yields substantially if followed by an overall weeding but two ring weedings were less effective than one late weeding in increasing grain yields.

Table 9 Effect of weeding practices and nitrogen on millet grain yield and Striga hermonthica populations.

	Yield as Q/ha			Striga as '000/ha		
	- N	+ N	Mean	- N	+ N	Mean
No weeding	2.18	1.67	1.93	3.68	3.76	3.72
Weed all X2	7.87	9.27	8.57	8.96	7.84	8.40
Ring fb all	5.68	6.66	6.17	7.76	6.16	6.96
Ring only X2	2.26	3.66	2.96	2.96	4.00	3.48
Late weed all	4.15	5.47	4.81	6.08	3.28	4.68
Weed all X1	7.20	10.05	8.63	3.84	6.16	5.00
Mean	4.89	6.13	5.51	5.55	5.20	5.37

Table 10 Variance ratios for millet: nitrogen weeding trial

Crop parameter	Weeding	Nitrogen	Interaction
Grain yield	42.79	29.92	3.32
1000 grain wt	6.88	1.22	2.79
Spike length	2.58	11.34	3.27
Spikes / ha	26.70	17.13	1.07
Plants / hill	14.79	0.13	0.61
Spikes / station	11.12	21.46	1.24
Striga population 25/8	1.05	1.29	2.65
23/9	0.64	2.52	1.52
21/10	0.60	0.11	1.29
Propn. crop with Striga	0.58	0.10	0.52

Examination of variance ratios in Table 10 shows significant weeding - nitrogen interactions on crop yield, notably spike length and grain size. Larger arithmetic grain yield increments were given per unit of nitrogen with better and earlier weeding.

No significant effect of weeding was observed on S. hermonthica. Plots weeded overall especially from mid- to late-season had higher

Striga populations than weedy plots at harvest. Nitrogen also reduced Striga populations, but not for all weeding practices (see Table 10).

Fertilizer use programme

The FAO-Niger Fertilizer Use Project demonstrations in the Zinder region clearly showed a marked reduction of S. hermonthica by the use of fertilizer. Population reduction was similar for full- and half-fertilizer rates (see Table 11).

Table 11 Effect of fertilizer on S. hermonthica populations and distribution within the crop

		Zero		Half		Full	
Location	Date	NS	NQ	NS	NQ	NS	NQ
Guidimouni	10/10	199	10	33	7	51	7
		42	8	46	8	4	2
		356	12	20	6	56	6
		2	2	0	0	0	0
		0	0	0	0	0	0
Guidiguir	10/10	39	7	3	3	1	1
		14	5	8	6	12	4
		28	10	10	8	11	4
		0	0	3	2	1	1
Gai	15/09	20	8	2	2	6	6
		12	5	1	1	0	0

NS = number of Striga plants/20 m^2
NQ = number of quadrats with Striga per 20 quadrats

Rates of urea on S. gesnerioides

Fertilizer had no significant effect on grain yield, thousand grain weight, Striga population, proportion of crop parasitised by Striga, crop survival or premature Striga death.

The average grain yield at Tarna, 18.53 Q/ha, was almost twice that at Magaria, 11.81 Q/ha. This increase was a result of heavier grains, 107.8 and 95.6 mg and more grains being produced at Tarna.

Phosphate increased grain yield by 1.1 Q/ha at Magaria. Nitrogen added slightly to this yield increment.

Striga populations of over 100,000 plants/ha were recorded at the final Magaria evaluation, whereas at Tarna final populations averaged

15 580 plants/ha. Increasing the nitrogen rate did reduce Striga density from 20 670 (untreated) to 8 650 plants/ha at Tarna. The proportion of plants parasitised followed the same pattern as Striga numbers with less than 50% crop parasitism at Tarna and more than 75% at Magaria.

The lack of a significant reduction in the S. gesnerioides population with nitrogen contrasts strongly with S. hermonthica where significant reductions are regularly reported.

Effect of intercropping cowpeas on S. hermonthica populations in millet

A non-significant reduction of S. hermonthica from 610 to 450 plants/ha was recorded over all the treatments at Kolo. Large blocks of pure and intercropped millet evaluated at Tarna showed a similar reduction in population of Striga from 1,540 to 760 plants/ha. No S. hermonthica was observed in the similar blocks at the INRAN Magaria station. Examination of data from the observation post surveys was less encouraging; almost half of the sites showed either no effect or an actual increase.

In spite of the low Striga populations the results are generally consistent with the hypothesis that weeds and an intercrop reduce the density of Striga. Modification of intercropping systems offers the farmer a positive advantage in Striga infested areas for little or no extra cost.

The herbicide 'AC 252,214'

S. gesnerioides populations were reduced by the herbicide 'AC 252,214' on average from 15 490 to 6 810 and 57 680 to 20 490 plants/ha respectively at Tarna and Magaria. Increasing the rates of herbicide decreased Striga density whereas changing the time of application had no consistent effect. Premature Striga deaths were not influenced by herbicide although a check in newly-emerged Striga numbers was observed shortly after herbicide application.

Increasing the rate of herbicide decreased grain yields; the highest rate, 400 g/ha, significantly reduced the yield compared with the untreated crop. This reduction was of the order of 4 Q/ha at both locations. Time of application showed no consistent trends. The higher grain yields at Tarna could be almost entirely accounted for by an increase in thousand grain weight from 70 (Magaria) to 100 g.

Crop phytotoxicity was especially severe with pre-sowing incorporation and early post-emergence applications at rates of 200 g/ha and above. The first 2 to 4 trifoliate leaves were chlorotic and very elongated, reduced almost to a mid-rib in extreme cases. Development was delayed. Pre-sowing incorporation of the herbicide delayed flowering and senescence of the crop. Late post-emergence application also delayed senescence.

Cenchrus biflorus and other grasses were completely controlled by pre-sowing, pre-emergence and post-emergence treatments at all rates. The growth of well established grasses was checked and some die-back occurred at the higher rates. Broad-leaved weeds were controlled for 2 to 5 weeks by all treatments. Zornia glochidiata and Alysicarpus ovifalius were checked by the herbicide but continued to grow as miniature plants until the plants were hand-weeded to assist Striga recognition. Aerial parts of Merremia tridentata were killed at all growth stages by the 2 highest rates of herbicide but some regrowth occurred from plants with large tap-roots.

The trials showed that systemic herbicides can be used to disrupt root parasites but in this instance no benefit was conferred on the crop because of phytotoxicity. In Nigeria, rates of up to 600 g/ha have been used without phytotoxicity. The very sandy soils in Niger are probably responsible for the difference in crop tolerance. One cannot however disregard differential varietal responses.

Varietal resistance

Cowpeas

More than 150 cowpea varieties have been evaluated for Striga resistance in various field screening trials at CNRA, Tarna during the past two years. Variety had no effect on the date of the first emerged Striga in most cases. The rate of increase in Striga numbers rose more rapidly in susceptible varieties. Erect or bush varieties and introductions from the USA, Senegal and Cape Verde were particularly susceptible to attack by S. gesnerioides. Prostrate varieties which were still vegetative in October were attacked later than those maturing in September, 90 to 105 days sfter sowing.

Comparison of the most Striga-resistant material from the INRAN, Niger and SAFGRAD breeding programmes in multi-locational yield trials has shown SUVITA-2 and TN 93-80 to be consistently among the most resistant cowpea varieties with good grain yields (see Table 12). KVx 70-183-3G and KVx 100-2 from SAFGRAD varied in resistance between years and sites.

Millet

Evaluation of material which had least Striga from breeding trials in 1985 and of some crosses from these materials was disappointing. Crop vigour was very poor without satisfactory Striga resistance. A major effort is needed to breed Striga susceptible millet suitable for small-scale farmers.

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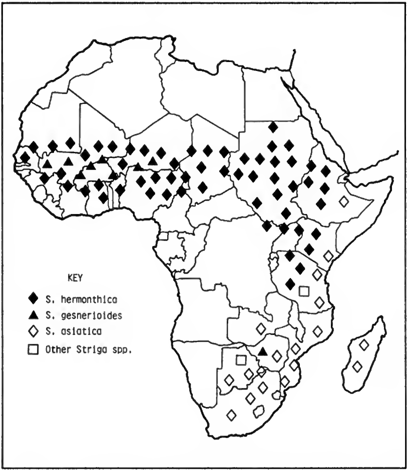
Table 12. Grain yields and Striga populations for selected cowpea varieties

Variety	Grain - quintals/ha					*Striga* populations				
		Tarna			Magar		Tarna		Magar	
	1985	1986a	1986b	1986c	1985	1985	1986a	1986b	1985	1986a
Mougne	12.95	7.28	-	-	3.88	18.52	17.32	-	86.81	28.39
Bambey-21	-	-	15.00	18.33	-	-	-	34.91	-	-
TN 88-63	22.00	14.94	11.73	-	12.94	13.49	22.53	23.31	86.18	21.44
Suvita-2	25.47	14.52	31.34	12.66	11.87	0.00	7.42	19.97	22.73	7.20
TN 80-80	-	-	21.77	10.18	-	-	-	34.72	-	-
TN 93-80	-	-	21.36	10.39	-	-	-	20.83	-	-
TN 121-80	-	-	5.41	0.35	-	-	-	26.91	-	-
KVx 30-183-3G	19.42	-	8.18	6.04	11.69	11.11	-	15.19	9.15	-
KVx 100-2	20.13	5.91	13.58	13.90	10.37	8.47	5.60	52.39	37.25	24.27
KVx 85-1	-	-	11.88	19.66	6.78	-	-	18.66	14.52	-
KVx 30-166-3G	20.04	-	12.24	13.44	0.94	14.29	-	64.24	47.98	-
LSD 0.05%	2.12			3.87	3.60		17 Sep	17 Sep		10 Sep
F	7.58	9.86	3.73	19.98	6.54					
CV	17.82		44.11	22.74	26.80					

Fig. 1. Map of Africa showing regions with agriculturally significant Striga species.



POTENTIAL TRAP CROPS AS A CULTURAL MEASURE IN STRIGA CONTROL FOR AFRICA

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Crop loss due to Striga infestation in the savannas of Africa cannot be over-emphasised. The loss in yield for sorghum and millet has been estimated to range from 20% to total crop failure resulting, in some cases, in relocation of villages (Doggett, 1965). Yield reduction in maize, under good management, has been estimated at 20 - 90% (Kim et al, 1986); similar estimates have been made for rice and cowpeas under heavy infestation by the parasite.

The limitation on cereal and cowpea production imposed by Striga species has resulted in important socio-economic consequences in many areas in Africa. The problem increases as new areas are brought under intensive cultivation and Striga seeds are moved across borders by grazing cattle in search of more fertile land and also through contaminated seeds brought by farmers who migrated from their original environment because of desertification. Striga is a very serious problem for small-scale farmers who must grow cereals for food.

Most of the infested areas already have a high build-up of seeds of the parasite in the soil and because yield loss is not just due to competition for environmental factors (nutrients, moisture, light), as in the case of non-parasitic weeds, it is essential to look for control measures that aim to reduce the level of Striga seed inoculum in the soil: to complement the efforts of plant breeders and to supplement in areas where varieties with a high level of tolerance to Striga have not yet been tested.

This test was in RCB design, four replications consisting of six maize varieties planted on plots that were heavily infested with Striga and on which soybean had been planted for three years. A similar trial was conducted in an adjacent field with a similar history of heavy Striga infestation but on which maize was planted for the previous three years. Both trials were well managed and received a basal compound fertilizer of NPK (15 - 15 - 15) at the rate of 400 kg/ha prior to land preparation and a side dressing with calcium ammonium nitrate (CAN) at the rate of 200 kg/ha four weeks after planting. A pre-emergence herbicide mixture of gramoxone and primextra was applied after planting and selective hand-weeding was carried out three times during the season to leave only plants of the parasite within the plot. Striga counts were made at 6, 8 and 10 weeks after planting and overall plant assessment made just before senescence.

Table 1. Mean Striga count and maize yield following 3 years continuous soybeans (A) and 3 years continuous maize (B).

A. Continuous soybeans

Maize varieties	Mean Striga count	Yield (t/ha)
8322 - 13	10.2	4.8
8428 - 19	14.8	4.6
8338 - 1	25.6	4.3
8322 - 13	3.0	2.6
TZSR - W - 1	19.5	3.0
Western Yellow	11.0	1.0
C.V. (%)	58.7	28.3
LSD (5%)	0.18	0.86

B. Continuous maize

Maize varieties	Mean Striga count	Yield (t/ha)
8322 - 13	98.3	4.3
8428 - 19	78.5	2.1
8338 - 1	207.5	2.6
8322 - 13	27.3	3.6
TZSR - W - 1	83.5	3.0
Western Yellow	23.6	0.8
C.V. (%)	53.6	26.5
LSD (5%)	0.25	0.97

The results (see Table 1) show that the Striga population in the plot under three years continuous cropping with soybean was significantly lower than in the plot under continuous maize for a similar period of time. The Striga tolerant hybrid maize variety 8322 - 13 gave the highest yield in both trials. There was a clear indication that three years continuous cropping of soybeans, in plots originally heavily infested with Striga, reduced the population of the parasite in a subsequent maize crop. The effect on yield of the susceptible hybrid 8338 - 1 is encouraging: 4.3 t/ha on the plot with continuous soybean compared with 2.6 t/ha on the plot with continuous maize. This effect may be due in part to the low Striga population in addition to the effect of soybeans.

Effect of soybeans on a *Striga* population, on maize-soybean intercrop and on rotation

This is the first year of a four-year trial to test the hypothesis that soybeans in rotation or intercropped with maize will reduce a *Striga* population in the cereal crop. The trial was planted in 6-metre, 8-row plots under good management in plots with a history of several years of heavy *Striga* infestation. In addition, *Striga* seeds harvested the previous year were mixed with sand and incorporated in the soil. Early results (see Table 2) indicated significant differences in *Striga* numbers between sole crop and intercropped maize.

Table 2. Comparison of *Striga* count and yield of maize planted sole and intercropped with soybean.

Treatment	*Striga* count	Yield (t/ha)
maize/soybean	72.3	3.0
sole maize	158.8	1.7
C.V. (%)	14.2	27.87
LSD (5%)	0.36	0.96

Discussion and Conclusion

Striga species are known to produce several thousands of microscopic seeds which can remain viable in the soil for up to 20 years. Germination of these seeds takes place only in response to chemical compounds exuding from the host root (Brown, 1965).

The germ tubes then make contact with and penetrate the host root cells extracting nutrient and moisture from the host which results in a pathological effect on the host and serious yield losses in cereals and cowpeas.

Because of its economic importance, there have been efforts to find effective control measures, one of which is to aim at reducing the seed population in the soil which is the primary source of inoculum. The first indication of the possible use of trap crops was the synthesis of strigol (Cook *et al*. 1972), a compound extracted from the roots of cotton (*Gossypium hirsutum*). This compound is capable of inducing seeds of the parasite to germinate but such seeds die shortly in the absence of a vulnerable host root. There were also several reports by farmers during interviews conducted in a survey of *Striga* species in Benin and Togo (Parkinson, 1985) that the level of infestation was always lower in a cereal crop planted after cotton. The fact that cotton consistently stimulated seeds of the parasite to germinate in vitro, but the resulting seedlings were unable to penetrate or colonise the host root cells, makes it desirable as a trap crop in controlling Striga in areas where cotton can be grown. (See Table 3).

Table 3. Induction of germination and emergence of S. hermonthica by potential trap crops and a suceptible maize variety.

Crop	Striga germination	Striga emergence
Soybean varieties		
TGX - 725 - 05D	33.4	0
TGX - 536 - 02D	33.0	0
TGX - 306 - 03E	32.3	0
Malayan	20.0	0
Cotton variety		
Samaru 77	40.8	0
Bambara groundnut		
TNS 512	21.0	0
Maize		
Hybrid 8338 - 1	24.8	0
C.V. (%)	5.3	
LSD (5%)	0.38	

The use of a trap crop in Striga control is practised in the United States where 200 000 ha were infested some 30 years ago (Garris and Wells, 1956). Soybean has been shown to reduce a population of S. asiatica in experiments conducted by researchers in the United States.

These results show that the effect is similar for S. hermonthica in maize. Even though soybean is not a popular crop in Africa, farmers showed that they would be willing to accept and adopt any control measures that would alleviate the Striga problem in the fields.

Bambara groundnut is another suitable crop which can be used as a trap crop in the drier Sudan and Sahel savannas where neither cotton nor soybean can be grown. This crop is already part of the cropping system in these areas, albeit small, and it would therefore not be difficult for farmers to increase its cultivation. It now remains for these potential trap crops to be tested in other ecological conditions with different Striga species and morphotypes and ultimately to demonstrate to farmers that it is one approach towards a solution of the problem.

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IITA'S STRATEGIES TO DEVELOP STRIGA RESISTANT MAIZE GERMPLASM

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INTRODUCTION

Striga spp. are a major constraint to cereal and cowpea production in the savannas of Africa. This consultation on *Striga* control is evidence of the severity of the problem and the concern of African governments, FAO and, particularly, African farmers.

In the past, *Striga* was recognised as a major constraint to sorghum and millet production in Africa but it was not considered so for maize simply because maize was not widely grown in the savannas. However, maize cultivation is rapidly increasing in these areas and, together with it, the parasitic weed *Striga*. Being in general stress-susceptible, maize is more vulnerable than sorghum and millet to parasitism by *Striga*, with yield losses under heavy infestation higher than 90%.

Realising the importance of the humid savanna belt for maize production, the rapid increase in maize cultivation in the area and the yield losses caused by *Striga*, scientists of the Maize Research Program of IITA have initiated work to develop maize germplasm tolerant or resistant to *Striga*. This paper describes the strategy adopted, the progress achieved during the last few years and the plans for future research.

STRIGA ON MAIZE IN AFRICA

To assess the spread of *Striga* in West Africa and the magnitude of the problem in maize, a survey was conducted in Nigeria, Benin and Togo (see Fig. 1). Results have shown that the following three *Striga* species are of economic importance in these countries:

Striga hermonthica. This species was found to be the most widely distributed, causing severe losses in maize, sorghum and millet fields. It is predominant in the drier areas.

S. aspera. This species seems better adapted to areas with higher humidity. It is morphologically similar to *S. hermonthica* and can be mistaken for the latter by untrained people. It appears that *S. aspera* is more virulent on maize than *S. hermonthica*.

S. asiatica. This was the least important of the three species seen in the countries surveyed. Red, yellow and white flowered variants were found. S. asiatica is the predominant species in eastern and southern Africa.

In general, the survey showed Striga spp. to be widespread causing severe losses in farmers' fields. Many fields have had to be abandoned because of Striga attack. Striga infestation was more severe in 1984 than in 1985 and observations in the current year (1986) indicate even lower levels of infestation in most of the savanna areas of northern Nigeria. It appears as though Striga infestation is related to the amount and distribution of rainfall, particularly at the beginning of the season. In contrast to the situation in northern Nigeria, a survey done in Ghana this year revealed high levels of infestation. In some locations, complete crop loss was observed. One possible explanation is that, unlike in Nigeria, rainfall in Ghana this year has been erratic (Ampong-Nyarko, personal communication).

YIELD REDUCTION ASSOCIATED WITH S. HERMONTHICA INFESTATION

In order to study the effect of Striga infestation on maize yield, an experiment was carried out in Mokwa, Nigeria in 1985. This location has records of Striga infestation in the past. An improved open-pollinated variety of maize, 'Ikenne-83 TZSR-Y-1', was sown under three levels of Striga infestation, namely, no Striga and moderate and high infestation. "Moderate" and "high" represent natural and artificially enhanced infestations, respectively. Fertilizer was applied at a rate of 400 kg/ha of NPK (15 - 15 - 15) and 200 kg/ha of calcium ammonium nitrate. Despite the heavy fertilization, yield reductions of 52 and 89% for the moderate and high levels of infestation, respectively, were observed when compared with the yield of the plot with no Striga infestation (see Table 1).

Table 1. Effect of different levels of Striga infestation on yield parameters of an open-pollinated maize variety 'Ikenne-83 TZSR-Y-1', Mokwa, Nigeria, 1985.

Level of Striga infestation	Striga no./plot	Striga rating	Yield (t/ha)	Yield loss (%)
0	0	1.0	5.4	0
moderate	68.3	2.3	2.6	52.0
high	231.3	4.8	0.6	89.0
C.V.	35.0	7.7	19.0	
LSD (5%)	60.0	0.3	0.9	

OPTIONS FOR *STRIGA* CONTROL

Various methods have been suggested for the control of this parasitic weed. They are: use of crop rotation and trap crops, herbicide treatments or other weed control measures and development of resistant/tolerant varieties. Eradication of *Striga* has also been attempted in the past. It is generally agreed that the best solution is an integrated approach that includes a combination of all the methods. Use of trap crops (eg, soybean, cotton), although effective in reducing *Striga* infestations, would be limited by the acceptability that these crops might have among farmers either for rotation or intercropping. The use of herbicides might be limited because of high cost or unavailability of the chemicals, especially for small-scale farmers. These factors account for the low rate of adoption and utilisation of herbicides as a means of weed control in Africa. Hand-weeding requires labour and if not done properly can increase the *Striga* problem.

Eradication has been attempted in the USA. Despite the high costs incurred and the excellent organisation of the programme, which includes strict quarantine measures, it has not been possible to eradicate this parasitic weed completely. A *Striga* eradication programme is not practical in Africa.

In consideration of the above factors, the Maize Research Program of IITA has decided to concentrate its effort in the breeding option. We believe this to be the best solution for the problem of *Striga* in Africa.

THE BREEDING APPROACH - TECHNICAL CONSIDERATIONS

Striga-resistant germplasm has been identified in sorghum and cowpeas. However, the resistance is not universal. A resistant variety developed in one country may not be resistant in another country. This is probably because of the existence of different biotypes of *Striga*. Development of resistant maize genotypes is further complicated by the presence of three different and economically important *Striga* species in Africa.

The objective of IITA's maize programme is to develop durable, multigenic resistant germplasm that will be effective against different biotypes of the same *Striga* species and hopefully against different species of the parasite. Three major resistance/tolerance mechanisms have been recognised: low or no production of *Striga* seed germination stimulant; factors affecting attachment and penetration of the *Striga* haustoria; and tolerance of the maize plant to *Striga* parasitisation. Identification and accumulation of resistance genes for the above three mechanisms can lead to the development of more durable resistance to *Striga*.

Unfortunately, as with many other stresses, Striga infestations are not uniform in space and time, making reliable screening for resistance difficult. It is therefore necessary to develop appropriate and reliable screening methodologies for the field, laboratory and/or greenhouse before launching a programme for resistance breeding. Screening techniques for the laboratory and greenhouse are particularly important to identify resistance mechanisms, such as those affecting Striga germination and attachment.

SCREENING TECHNIQUES FOR STRIGA RESISTANCE

Good screening techniques should be simple, inexpensive and suitable for testing large numbers of plants. Non-destructive tests of individual plants are desirable. It is also recognised that the ultimate test should be done under field conditions in different locations.

Identification of non/low-stimulant producer maize plants.

To identify non/low-stimulant producer maize genotypes, Striga seeds are sterilised and pre-conditioned for seven days on moist fibre glass filter paper in petri dishes or plastic growth pouches before pre-germinated maize seeds are introduced into them. Germination of Striga seeds could be observed within three days. The growth pouch technique is more efficient because it is easier to handle and requires less space. Screening in greenhouse or screenhouse is complementary to observations made in the laboratory.

The most promising technique developed so far is that of the double-pot. Maize seeds are planted in a small plastic pot with a perforated bottom. The pot is placed on top of a similar pot in which a filter paper with Striga seeds is placed at the bottom. Both germination of the Striga seeds and attachment to the maize roots can be observed with the aid of a magnifying glass. One of the major advantages of the double-pot technique is that it is non-destructive and can be used with individual plants. The above techniques are not yet sufficiently refined to be used effectively in screening large numbers of maize genotypes. However, by using both petri dishes in the laboratory and pots in the greenhouse, four inbred lines and two hybrids with known reaction to Striga under natural field conditions were tested for stimulant production. Significant differences in germination of Striga seeds were observed (see Table 2). The results of the two methods were similar and well correlated with the field observations.

Table 2. Induction of Striga seed germination by susceptible and tolerant maize inbred lines and hybrid varieties, 1985.

Inbred lines or hybrid varieties	Germination of Striga seeds (%) Pot	Petri dishes	Field rating*
5057	39.8	25.6	4.6
1368	40.9	30.7	4.0
9071	16.2	20.0	1.9
9848	8.2	7.1	2.0
8322-13	12.2	9.0	1.5
8338-1	25.1	19.0	4.3
LSD (5%)	1.7	2.5	
C.V.	8.0	15.8	

* 1 = resistant; 5 = highly susceptible

Identification of maize genotypes tolerant of possible Striga toxic effect.

Early symptoms of Striga infection in the field suggest the possible involvement of toxins in the disease etiology. Attempts have been made to inject crude extracts of Striga into the stem of maize seedlings. When this was done, necrotic symptoms developed at a distance from the injection point. However, this technique does not yet give consistent results and additional work is required to improve it. When developed, the technique can become a very useful method of screening many maize plants under field conditions.

Field infestation techniques

Efforts are currently under way to develop field infestation techniques to enhance the natural infestation level and to create uniformity of infestation. Breeding research requires large areas. For this reason, large amounts of Striga seeds are required, and it is important that they be uniformly distributed in the research plots. Methods that will economise on Striga seeds and save labour, while also ensuring uniform establishments are being studied. Excellent and uniform infestations have been achieved in some instances but the techniques still need to be improved. The results obtained so far indicate that good methodolgies can be developed. But, better understanding of the factors affecting Striga germination is needed.

PROGRESS IN BREEDING FOR STRIGA RESISTANCE/TOLERANCE

Breeding for resistance/tolerance to Striga so far has been conducted in a naturally infested field in Mokwa, Niger State, Nigeria. Striga hermonthica is the only species found in this field. Despite the difficulties of working under a natural infestation, good progress has already been made. Inbred lines with different response to S. hermonthica have been identified (see Table 3).

Table 3. Striga ratings of some white and yellow grain maize inbreds, Mokwa, Nigeria, 1984.

Inbred	Original code no.	Striga rating	Origin
White grain			
TZI 14	9043	1.5 a	Rpp TZSR-Y x N28
TZI 11	9006	1.6 a	Mo17 x RppSR
TZI 3	1368	3.4 b	Across 7721 x TZSR
TZI 32	5068	3.6 bc	Tlalt. 7844 x TZSR
TZI 2	1201	4.4 cd	Across 7622 x TZSR
Yellow Grain			
TZI 24	9432	1.5 a	H95(3) x RppSR
TZI 30	9848	2.0 ab	Hi29(2) x RppSR
TZI 25	9450	2.6 bc	B73(3) x RppSR
TZI 22	7103	3.3 cd	TZESR-Y
TZI 29	9613	4.0 d	FRI3A(3) x RppSR

1. Striga rating: 1 = resistant; 5 = susceptible
   Ratings not followed by the same letter differ significantly (5%) by Duncan's new multiple range test.

2. Number of backcross generations in brackets.

Hybrids with an acceptable level of tolerance have also been developed (see Table 4).

The performance of two hybrids, 8338-1 (susceptible) and 8322-13 (tolerant), under different levels of Striga infestation was tested in Mokwa during 1985. The two hybrids were planted side by side across the breeding nursery. Striga infestation was rated on a 1 - 5 rating scale, where 1 represents no infestation and 5 represents a high infestation. Yields were measured from 2-metre long rows in 4 replications from areas with different degrees of infestation. Both hybrids yielded the same in areas free from Striga. The yield of the

Table 4. Grain yield (t/ha), *Striga* counts and rating of seven selected hybrids and open-pollinated varieties, Mokwa, Nigeria, 1985.

Hybrid/variety	*Striga* count	*Striga* rating	Grain yield
8322-13	199.8	2.0	6.9
8425-9	52.0	1.5	6.6
8329-15	77.0	2.1	6.1
8329-21	138.3	3.4	4.6
8434-6	154.5	4.3	4.3
EV 8443-SR	247.5	3.4	4.2
Ikenne-83 LSR-Y-1	247.5	4.0	3.7
C.V.	67.8	30.7	26.6
LSD (5%)	126.2	1.3	2.1

1. Average of four replications
2. *Striga* counts at 12 weeks after planting;
3. *Striga* rating scale 1 - 5; 1 = resistant, 5 = susceptible.

susceptible hybrid 8338-1 was reduced to a much greater extent than that of the tolerant hybrid 8322-13 where *Striga* infestation was high (see Table 5). The yield differences between the two hybrids increased with increasing level of *Striga* infestation. Under moderate infestation, the tolerant hybrid yielded about twice as much as the susceptible one.

Table 5. Grain yield (t/ha) and yield index (%) of susceptible (8338-1) and resistant (8322-13) maize hybrids under *Striga hermonthica* infestation at Mokwa, Nigeria, 1985.

	8338-1		8322-13		Yield
Striga rating	grain yield	yield index	grain yield	yield index	index of var1/var2
1	7.7	100	7.6	100	98
2	5.5	71	7.5	99	136
3	3.5	46	6.2	81	177
4	1.9	25	4.6	60	242
5	0.7	9	2.7	36	386
LSD (5%)	0.9		1.5		
C.V.	15.4		17.6		

Preliminary studies indicate that different maize inbred lines may have different genetic mechanisms controlling the reaction to *Striga* (see Table 6). The hybrids, 8322-13 and 8321-18, are tolerant of this parasitic weed. In both hybrids, line 1368 is a common susceptible parent. The other two lines, 9030 and 9071, used to develop these two hybrids, have similar origin (N228 x TZSR) and are tolerant. In the two hybrids, the F_1 showed the same *Striga* rating as the tolerant parent. On the other hand, in 8338-1, the F_1 between the tolerant line (5012) and susceptible line (5057) showed a similar rating to the susceptible parent indicating that, in this case, tolerance is recessive. The tolerant line in hybrid 8338-1 has a different origin from the other two tolerant lines. It is possible that the level of tolerance to *Striga* can be further increased by crossing tolerant lines from different origins.

Table 6. Grain yield (t/ha) of three hybrids and rating for *Striga hermonthica* damage of the hybrids and their parental lines, Mokwa, Nigeria, 1985.

F_1 hybrid	Yield	*Striga* rating	Tolerant inbred line	*Striga* rating	Susceptible inbred line	*Striga* rating
8322-13	7.2	1.5	9030	2.0	1368	3.4
8321-18	6.5	1.9	9071	1.9	1368	3.4
8338-1	4.3	4.3	5012	2.0	5057	4.6

Origin of inbred lines:

9030 (Rpp TZSSR-Y xN28); 9071 (N28 x TZSR);
5012 (Sids 7734 x TZSR); 1368 (Across 7721 x TZSR);
5057 (Tlalt. 7844 x TZSR).

The reactions of different maize genotypes to *Striga* vary. Thirty-seven new inbred lines were crossed to a known susceptible line (1393) in 1984. Three replications of the test crosses were planted in a highly infested area at Mokwa in 1985. *Striga* counts 12 weeks after planting, *Striga* ratings on a 1 - 5 scale and grain yield were recorded. Grain yields were highly negatively correlated to *Striga* rating (r = -.693) and *Striga* counts (r = -.498). However, a low correlation (r = .273) was found between *Striga* counts and ratings (see Figs. 2 and 3). This indicates that among the testcrosses there were differences in the degree of tolerance. This is particularly evident at the range of 75-125 *Striga* plants/plot.

Similarly, under very low *Striga* counts, severe symptoms of *Striga* infestation were found (see Table 7).

Table 7. Striga counts 12 weeks after planting and Striga rating of several inbred lines, Mokwa, Nigeria, 1985.

Inbred line	Striga count/5m row	Striga rating (1-5)
4001	2.5	1.0
9043	7.5	1.3
5012	2.0	2.0
9071	10.5	2.3
1394	24.0	3.0
1368	5.5	4.0
9091	0.0	4.5
5057	4.0	4.8
4045	0.0	5.0

A closer examination of plants of lines with high Striga rating but low Striga counts such as 4045 and 9091, revealed the attachment of many underground Striga plants to them. The maize plants were killed before Striga emergence, suggesting a possible action of Striga toxins.

The need to develop a range of varieties

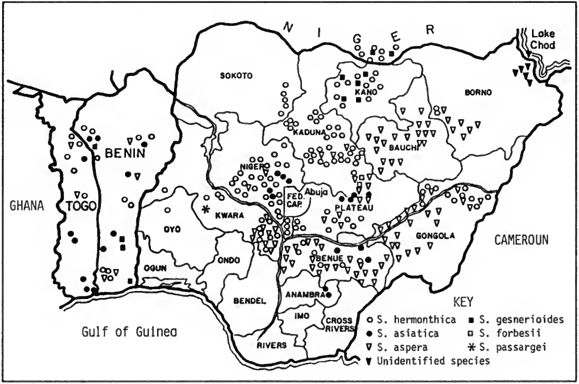
Africa is a continent with many countries, ecological conditions and cropping systems as well as people with different tastes and preferences. IITA's Maize Research Program recognises that the development of one Striga-tolerant variety is far from being sufficient. For example, for another stress, maize streak virus, many resistant varieties have been developed. The varieties are different in their ecological adaptability, range of maturity and grain colour and texture. A similar approach should be taken with regard to Striga. The varieties with resistance to Striga will have to be resistant to other stresses as well. Because of the need to work under erratic natural infestations, more effort has been devoted to the development and testing of inbred lines and hybrids rather than open-pollinated varieties since hybrids and inbred lines are genetically uniform. But considering that many small-scale farmers will not be able to use hybrids, a number of open-pollinated synthetic varieties will be included in an international testing programme in 1987. Some efforts have gone also into breeding by the population improvement method. As soon as the proper screening methodologies are developed and/or improved, the work on population improvement which leads to the development of open-pollinated varieties will be intensified.

Concluding remarks

Striga species have long been recognised as major constraints to cereal production in the savannas of Africa. However, until recently, no attempts were made to develop *Striga* resistant maize germplasm. Based on past experience with other crops and the existence of different *Striga* species and biotypes, many people do not believe that the breeding approach is a practical one. This scepticism is not shared by the maize scientists at IITA. We initiated breeding activities for the development of *Striga* resistant germplasm in 1982. Maize is a crop with tremendous diversity. Genes for resistance to many diseases and insects have been identified and it is almost certain that genes for *Striga* resistance also exist. The challenge now is to identify and accumulate them in a rational way. We believe that the major obstacle at present is the unavailability of reliable screening methodologies. Therefore, our highest priority is the development of these methodologies. To do so, we need a much better understanding of *Striga* biology and its interaction with the host plant. We hope to do the necessary research in cooperation with different universities or research institutions. Once these methodologies are available, IITA maize scientists are confident that a range of resistant varieties, that combine low stimulation for seed germination or low haustoria attachment with tolerance to *Striga* parasitism, can be developed. The encouraging results achieved so far support our optimism.

The availability of resistant varieties together with appropriate cultural practices can solve the problem of *Striga* in Africa. However, it should be realised that in order to do so we need both time and resources.

Fig. 1. Map of Nigeria, Benin and Togo showing locations of _Striga_ species.



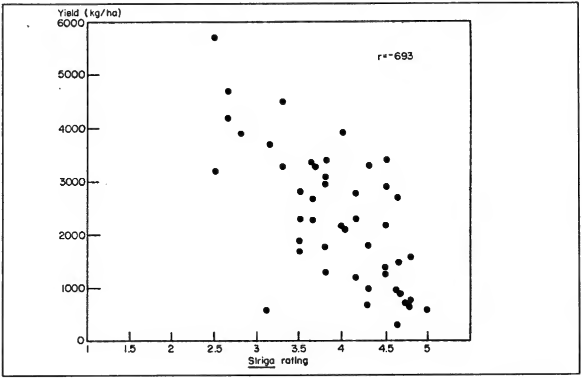
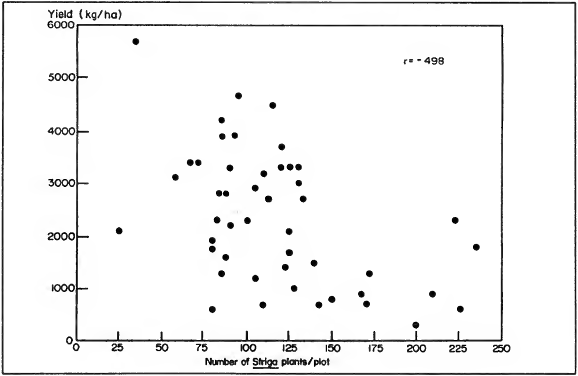


Fig. 2. Relationship between *Striga* rating (1-5 scale) and yield of various genotypes in test crosses with a susceptible inbred line 1393.

Fig. 3. Relationship between number of Striga plants and yield of various genotypes in test crosses with a susceptible inbred line 1393.



ICRISAT'S BREEDING PROGRAM FOR *STRIGA* RESISTANCE IN SORGHUM AND MILLET IN AFRICA

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INTRODUCTION

Striga resistance breeding efforts were scanty before ICRISAT started working in Africa in 1979. Past efforts in South Africa, East Africa and Nigeria concentrated on the identification of resistance in sorghum (Ramaiah, 1983). Efforts on millet were non-existent and as such, resistant millets were unknown in Africa. ICRISAT's *Striga* programme in Africa started in 1979 with financial assistance from the International Development Research Centre (IDRC). This programme has benefited very much from the breeding material generated in the *Striga* project which started in 1975 at ICRISAT - India. This paper summarises the results obtained in ICRISAT's African *Striga* breeding programme since 1979.

OBJECTIVES

The objectives of the *Striga* project are as follows:

a) Identify stable sources of resistance to *Striga hermonthica* in sorghum.

b) Screen local millet germplasm with a view to identifying resistant millet varieties.

c) Improve the resistant sorghums and millets for yield and other agronomic traits through breeding.

d) Understand the genetic resistance.

e) Study the physiological strains of *Striga hermonthica* in relation to host plant resistance.

f) Explore various agronomic practices in integrated *Striga* management.

g) Cooperate with national programmes in Africa by supplying promising genetic material.

h) Train nationals in *Striga* research.

IDENTIFICATION OF SOURCES OF RESISTANCE IN SORGHUM

Sources of Resistance from ICRISAT Centre

A total of 145 sorghum varieties and breeding selections brought from the Striga in India were screened against Striga hermonthica in Burkina Faso in 1979 (ICRISAT/Burkina Faso, 1979). Most of the lines were unadapted to West African conditions; they were early, susceptible to grain mould, smut, and poor establishment and were also susceptible to Striga hermonthica. Three varieties, N 13, SPV 103 and Framida, had a good level of resistance.

Low Stimulant Lines

The sorghum world collection is being screened at the ICRISAT Centre in India for the ability to produce Striga seed germination stimulant using double pot techniques (Parker et al. 1977). So far, about 16 000 varieties have been screened from which about 620 varieties that do not produce germination stimulant or produce only small quantities have been identified (Striga seed germination <10% of susceptible check). A first batch of 200 such varieties was screened in S. hermonthica-sick plots during 1980-1982 and IS 8961 and IS 9830 were promising. Further tests revealed that, so far, the variety IS 6961 has the highest level of resistance available in sorghum. In 1985 and 1986, a complete set of 620 varieties were screened in pots and nine of them were selected as resistant. They are listed in Table 1. Out of these, IS 6961 and IS 8140 were reported by Parker (1980, personal communication) to be low stimulant producers.

Working and Basic Collections

Screening in the laboratory was concentrated on low stimulant character and did not consider other forms of resistance because of a lack of simple screening techniques. Therefore, the working collection (630 varieties) which represents the agronomically good lines was evaluated against S. hermonthica in 1980 and 1981; however, none was resistant.

A basic collection of 600 varieties was also evaluated without success. This clearly demonstrated that direct field evaluation of germplasm is less successful. On the other hand, evaluation in the laboratory for stimulant production and subsequent field testing resulted in few resistant varieties.

Local Collections

Twenty-nine seguetanas (varieties resistant to *Striga*) from Mali were evaluated for field resistance from 1981. Two varieties, ICSV 1019 BF (Sg 5153) and ICSV 1020 BF (Niarabougou), with good levels of resistance, were selected. Out of several Burkinabe varieties screened, ICSV 1018 BF (CVS 122) showed some promise in Burkina Faso and Cameroun. Tetron from Sudan was moderately resistant but three of the varieties from Ethiopia were susceptible in Burkina Faso.

Striga Resistance in Pearl Millet

In 1979, there were no known sources of resistance to *S. hermonthica*. To start with, 90 varieties representing the West African pearl millet collection were screened. Varieties with high levels of resistance were not found. A breeding programme was started in which the less susceptible lines were intercrossed in order to increase the levels of resistance. The programme continued to evaluate segregating generations in the field while selection within parental lines continued in *Striga*-sick fields located in Aourema (near Ouahigouya in Burkina Faso) and Tarna (near Maradi in Niger). Three years of field screening and evaluation based on the mean performance of the progeny did not result in any progress. Pot experiments were started in 1982 to screen individual millet plants. Planting in pots in the summer months (March/April) was found to be extremely good to differentiate varietal differences. Susceptible plants were completely killed. The resistant plants were self-fertilised and the progeny tested in several plots. Selfing and selection by progeny testing in pots was continued for two seasons. Promising progenies were field-tested in 1984 and 1985. Some of the most promising progenies were selections from 3/4 HK-2-2. Other promising selections came from Inbred 5258, Serere 2A-9, P 2627, etc. Population improvement using recurrent selection also yielded some encouraging results. Some of the promising progenies are 84V 801 and 84V 696.

Twenty-five local varieties from Burkina Faso, 56 germplasm lines from GRU/ICRISAT Centre, 34 local collections from Senegal, semi-wild millets (Shibras) and 1MZAT trials were also screened but no useful resistant lines were found.

Inheritance of Resistance to S. hermonthica in Sorghum

Genetic analysis of resistance to *S. hermonthica* was carried out using diallel, line x tester and generation means analyses (1CRIST/ Burkina Faso, 1982).

Diallel analysis using parents (N 13, Framida, SPV 103, IS 9830, BTx623, VS 702 and IS 9839), F_1S and F_1S have clearly demonstrated the importance of additive genetic variance in determing the expression of Striga resistance. Dominance genetic variance was of less importance. For yield related traits, both variances were important (Ramaiah, 1983 and 1986). The line x tester analysis using some other resistant varieties like IS 6961, 10839, Tetron and Seguetana as females and CSV 4 and E 35-1 as males also demonstrated the importance of additive genetic variance compared to dominance variance (Ramaiah 1986). This was further confirmed by generation means analysis using N 13, Framida and SPV 103 as resistant parents.

The segregation pattern in the F_2 and back-cross generations of two sets of crosses (N 13 x BTx623 and IS 9830 x BTx623) indicated the possibility of one gene controlling Striga resistance in both crosses. The resistance exhibited partial dominance in the F_1. In the F_2 and back-crosses, the segregation was as expected, based on gene control, resistance being dominant (Nabayaogo Pierre, 1984). However, heritability of Striga resistance as measured by the emerged number of Striga plants was low. Therefore, progeny testing of the F_3 should be more effective for Striga resistance than individual plant selection in the F_2.

Improving Striga Resistant Sorghum Varieties for Yield and Other Agronomic Traits

Most of the Striga resistant sorghum varieties lack any resistance to grain mould, shoot fly, stem borer, midge, etc.,and are agronomically inferior for general cultivation by farmers. The negative correlation between yield potential and resistance traits calls for a breeding programme to break this association. Unfortunately, most of the resultant varieties are also poor combiners resulting in very few desirable segregants. Careful selection of parents in a crossing program is vital for the success of the breeding efforts. At ICRISAT, the improvement of Framida and N 13 for various agronomic traits was started as early as 1977. With Framida, the red grain colour was successfully changed to white and the purple plant colour was changed to tan. Some of the most promising selections are ICSV 1005, 1006 and 1007 BF. They have exhibited good levels of resistance to S. hermonthica in Burkina Faso (ICRISAT/Burkina Faso, 1984). They were also resistant to a broad spectrum of S. hermonthica samples when tested in the laboratory (Parker, personal communication). All these selections are white and mature earlier than Framida. ICVS 1007 BF exhibited resistance throughout the Striga belt (India, East and West Africa and the USA). This variety is an excellent source of stable broad-spectrum resistance for further improvement. It showed resistance in Niger during the 1986 crop season (Dale Hess, personal communication).

Another selection, ICSV 1002 BF, from a cross between E 35-1 and Framida is very promising. It combines the good characters of both varieties. It has better stand establishment, stability of yield under good and traditional management, moderate levels of resistance to Striga (all characters from Framida), white grain with good food quality, resistance to leaf disease and delayed senescence (all from E 35-1). This variety has been tested on farmers' fields by ACPO/SAFGRAD in Burkina Faso since 1984 with encouraging results and may be proposed for extension in due course. Several farmers in Mossi Plateau of Burkina Faso are already growing it.

The improvement of IS 6961, which has a very high level of resistance but is otherwise poor agronomically, has recently been started. IS 6961 is tall, late, low-yielding with a poor harvest index and lodges. Unlike Framida, IS 6961 gave very few desirable segregants when crossed with the high yielding varieties. Early short segregants will be selected in the F_2. F_3 progenies will be tested in Striga-sick plots and selected progenies back-crossed to a high yielding variety and/or inter-crossed to improve yield further.

Physiological Strains

Strains. There exist strains in S. hermonthica that are specific to sorghum and millet. The specificity appears to be based on their requirements for different germination stimulant compounds in host root exudates (Parker and Reid, 1979). Evolution of extreme crop specificity in West Africa may be due to the reproductive isolation which could be the result of (a) geographic isolation and/or (b) isolation in time (Ramaiah, 1984). These two factors gradually separated millet and sorghum strains and resulted in reproductive isolation. However, intermediate hybrid forms do appear in transition zones where sorghum and millet are grown together and S. hermonthica on both crops flowers at the same time.

Zonation of Striga distribution. With the help of extensive field surveys and pot and field experiments, the geographic distribution of Striga in West Africa was determined. Variability was observed in the North-South transect. Four Striga zones were identified (ICRISAT/ Burkina Faso, 1980).

Zone 1. Locations in the northern-most region (around 350-500 mm rainfall) which are above latitude 13° N, namely Ouahigouya, Dori, Gorom Gorom (all in Burkina Faso), Maradi (Niger) and a few northern locations in Senegal. All these have only one Striga strain which is specific to millet.

Zone 2. Locations in Mali north of Fana, Bla, San, Tominian and Benena having remarkable similarities with locations exemplified by Djibasso, Gourey, Zandkom, Roumassi and Korsimoro in Burkina Faso and the region between Katsina and Kano in Nigeria, latitude around 13° N. Both sorghum and millet strains exist and hybrid forms are found.

Zone 3. The region between 12 and 13° N with a rainfall of 650-800 mm remarkably belongs to the sorghum strain of Striga. The locations are Kamboinse, Kokologo, Koudougou, Saria, Dedougou, Honde, Boromo, Boni, Sabou, Kombissiri (all in Burkina Faso), Kousi, Koutiala, Bla, Fana and Bamako (all in Mali).

Zone 4. In this zone between 11 and 12° N, both strains are found. Striga zones closely follow the crop and ecological zones in West Africa indicating their adaptation to different host crops.

Significance of zonation. In zone 1, it is not necessary to have Striga resistance in sorghum cultivars as sorghum represents such a small proportion of the cropped area. Similarly in zone 3 there is no need for Striga resistant pearl millet cultivars. Thus sorghum and pearl millet have one zone each where they do not need Striga resistance.

The millet collected in zone 3 as "Striga-free" may not really be resistant in zone 1 because it does produce the root exudates capable of stimulating the pearl millet Striga strain in zone 1 to germinate.

Millets collected in zone 4 as "Striga-free" could be a useful source of resistance. They cannot however be directly introduced into zone 1 because of photosensitivity.

Cooperation with National Programs

The ICRISAT Striga programme in Africa supplied Striga-resistant sorghum varieties to various national programmes either in the form of trials or bulk quantities of selected varieties. Trials were sent regularly to Ghana, Niger, Nigeria, Cameroun, Sudan, Kenya and Ethiopia. Varieties like ICSV 1006 and ICSV 1002 BF were tested by the IPM Project in Gambia and all the cooperating countries (Ramaiah, 1983). Framida exhibited resistance in many of thee countries. It is doing well as a variety in Burkina Faso and Togo. It is under extensive testing in Ghana. Large quantities of ICSV 1002 BF have been supplied to Cameroun (ACP/SAFGRAD) and Niger (FAO).

Summary and Conclusions

The existence of varieties of sorghum resistant to S. hermonthica is confirmed. Some of the most promising are Framida, N-13, IS 6961 and IS 9830. Screening in the laboratory for low stimulant production helped in the identification of a few field resistant varieties such as IS 14825, 14829, 14928, 7739, 7777, 16184, 8140 and IS 16396. Most of the resistant sources are agronomically poor and unacceptable for large scale cultivation by the farmers. Genetic analysis of field resistance of sorghum varieties to S. hermonthica demonstrated the possibility of selecting for high yielding Striga-resistant lines in a breeding programme. Breeding efforts to improve the agronomic desirability of resistant varieties like Framida resulted in some promising lines like ICSV 1005, 1006 and 1007 BF which combined resistance and yield. Physiological strains of S. hermonthica specific to sorghum and millet were confirmed. Geographic distribution of S. hermonthica in West Africa was defined and its importance in the breeding program highlighted. In pearl millet, the identification of resistant varieties was difficult. Nevertheless, some selections from a local variety, 3/4 HK, have exhibited less susceptibility and need further evaluation.

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AN APPROACH TO COWPEA STRIGA CONTROL THROUGH PLANT BREEDING

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INTRODUCTION

The parasitic weed, Striga gesnerioides, attacks cowpea in most parts of the semi-arid tropics of West Africa, but the most seriously infested areas are localised in the Sudan and Sahel Savanna areas of Mali, Burkina Faso, Niger and Nigeria. The problem becomes more serious when Striga infestation coincides with drought stress, a commonly occurring feature in these areas. Fields once infested with this parasite are difficult to clean. Striga seeds can remain viable for long periods and as soon as a susceptible variety is grown in an infested field, it stimulates germination of the parasite.

Several control measures such as up-rooting of emerged Striga, crop rotation, trap cropping, etc, can be useful to some extent, but they do not provide a long term aolution. Use of chemicals like ethylene gas can eradicate Striga, but it is expensive and requires specialised equipment which peasant farmers cannot afford. Therefore, the easiest and most economical way to overcome the problem is the use of resistant varieties.

With this objective in mind, the International Institute of Tropical Agriculture (IITA) initiated a program to identify or develop Striga-resistant varieties for the affected areas. The program is headquartered at Kamboinse, Burkina Faso.

Since the beginning of 1981, considerable progress has been made in meeting the above-mentioned objective. Resistant varieties have been identified and the resistance has been combined with other desirable traits. Several newly developed varieties have been identified by different national programa for use in their countries. Details of this work are discussed in this paper.

IDENTIFICATION OF RESISTANT VARIETIES AND CONFIRMATION OF RESISTANCE

In an experiment conducted in 1981 at Kamboinse with about 50 elite cowpea varieties included at that time in different advanced and uniform yield trials, two varieties, SUVITA-2 (formerly Gorom local) from Burkina Faso and 58-57 from Senegal, were found to be free from Striga attack (IITA/SAFGRAD Annual Report, 1981). These varieties were further evaluated both in the field and in the screenhouse at Kamboinse and it was confirmed that they were resistant to S. gesnerioides at that location (Aggarwal et al. 1984 and Aggarwal et al. 1986). In addition, several new varieties including IT83D-226, IT82D-450-4, IT82-479-1 and IT81D-994, received from IITA, Nigeria, were found to be resistant (IITA/SAFGRAD Annual Report, 1985) but when retested at Kamboinse in 1986, showed a low level of susceptibility. Out of these, the origin of IT83D-226, IT82D-479-1 and IT82D-450-4 was traced back to SUVITA-2 (B.B. Singh, IITA, Ibadan personal communication) indicating that their resistance was transferred from SUVITA-2. Thus they did not seem to represent new sourcea of resistance. However, the variety IT82-994 was not derived from SUVITA-2. A request has therefore been made to get seeds of its parents to find out the origin of its resistance.

PRESENCE OF DIFFERENT STRAINS OF STRIGA

Testing of varieties in the beginning was limited to Burkina Faso. Since Striga is a serious problem in other countries, SUVITA-2, 58-57 and some varieties derived from SUVITA-2 have been tested in Mali, Niger and Nigeria in the last few years. The most striking result obtained was that varieties resistant in Burkina Faso were not necessarily resistant in other countries (see Table 1). This indicated the presence of different strains or populations of S. gesnerioides in these places. Because of the fear of introducing new strains of Striga into Burkina Faso, a collaborative research project was established with Dr. C. Parker of the Weed Research Division, Long Ashton Research Station in England to verify if, in fact, there are different strains of Striga. Dr. Parker and his group tested cowpea varieties with different strains obtained from Mali, Burkina Faso, Niger and Nigeria and the results clearly indicated the presence of different strains.

In general, SUVITA-2 showed complete resistance to both Mali and Burkina Faso strains and susceptibility to strains from Niger and Nigeria (Parker, personal communication). This is also reflected in data from Burkina Faso (Aggarwal and Haley, 1986). Research was then initiated by Dr. Parker to find varieties of cowpea that might be resistant to all the strains of Striga. After testing varieties from several countries, Dr. Parker and Miss Polniaszek identified a variety from Botswana called B-301 (originally recommended as resistant to Alectra vogelii by Mr Riches) showing resistance to Striga strains from Mali, Burkina Faso and Niger (personal communication). Although the results are preliminary, they offer an opportunity to find or develop varieties of cowpea resistant to other atrains of S. gesnerioides.

Seeds of B-301 have been obtained and initial tests to verify its resistance are under way. In anticipation of its multi-strain resistance, crosses have also been initiated with other promising varieties adapted to conditions in these countries. In 1987, this variety will be tested in other countries.

DEVELOPMENT AND TESTING OF NEW STRIGA RESISTANT VARIETIES

From the cropping season 1983, a systematic testing program in the form of regional variety trials was initiated by IITA/SAFGRAD with the objective of testing new varieties of cowpea for their resistance to Striga at other locations and for their overall adaptation. Results of three Regional Cowpea/Striga Trials (RCST's) conducted in collaboration with various national programs in 1983, 1984 and 1985 have recently been compiled. Yield (kg/ha) and percent of cowpea plants infested with Striga at different locations during the 3 years are presented in Tables 1, 2 and 3 on pages 152 - 154. As anticipated, the level of resistance of newly developed varieties was much higher in Burkina Faso than at other locations. Nevertheless, several varieties performed quite well both in terms of resistance and yield in other countries.

In summary, the following varieties looked promising in different countries:

Mali	Kporo:	KVx 30-183-3G KVx 65-114	SUVITA-2 KVx 61-74
Niger	Maradi:	KVx 30-183-3G	SUVITA-2
	Magaria:	KVx 30-183-3G	KVx 30-323-1G
Nigeria	Kano:	KVx 30-183-3G KVx 100-2	SUVITA-2
	Bakura	KVx 30-403-1G	KVx 100-2

Burkina Faso

Kamboinse & Ouahigouya: Several, but most promising were:

SUVITA-2	KVx 71-74
KVx 65-114	KVx 183-2

COMBINING RESISTANCE TO STRIGA WITH OTHER CHARACTERS

In addition to Striga infestation, other constraints on cowpea production in the semi-arid areas are insect pests, drought and diseases. It is therefore necessary that Striga resistance is combined with other desirable traits. Notable progress has been made in combining resistance to *Striga* and the storage pest *Bruchid maculatus*. Several varieties, namely KVx 30-G172-1-6K, KVx 30-G183-35K and KVx 30-G200-1-3K, have been developed which combine these resistances together with good seed quality and high yield (Aggarwal *et al.*, 1986). However, the above-mentioned varieties were found to be slightly late in maturing and susceptible to pod blotch (*Colletotrichum* spp.) and bacterial blight (*Xanthomonas vignicola*), the two most important diseases found in these areas. In an effort to improve these varieties for these characters, they were crossed with IT82D-716, a multiple disease- and bruchid-resistant variety developed at IITA, Nigeria. Preliminary yield evaluation of this material was carried out in a *Striga*-infested plot at Kamboinse in 1986. Several of the selections looked quite promising for their level of resistance to diseases and to *Striga* and, in addition, possessed desirable seed quality and high yield (IITA/SAFGRAD Annual Report, 1986). Single plants have been selected from promising selections, for bruchid bioassay in the laboratory.

Considerable progress has also been made in combining *Striga* resistance with resistance to the aphid *Aphis craccivora*, along with good seed quality. This material was evaluated for yield for the first time in 1986 but the results are not yet conclusive.

Some progress has also been made in combining resistance to *Striga* and resistance to drought. SUVITA-2, which is resistant to *Striga* is also widely adapted to the harsh dry conditions. New varieties have been developed by crossing SUVITA-2 with other varieties adapted to the dry areas. Most of these varieties have already been tested in the RCST and their performances are given in Tables 1, 2 and 3. Amongst the most promising varieties that combine *Striga* and drought resistance are KVx 61-74 and KVx 65-114, both developed by crossing SUVITA-2 with TVx 3236. Both possess a good level of resistance to diseases and have desirable seed quality (IITA/SAFGRAD Annual Report, 1985).

Another variety which looked quite promising in 1986 was KVx 183-2, developed by crossing SUVITA-2 with IT82D-716. A limited quantity of seeds of these varieties is available through the IITA/SAFGRAD Program in Burkina Faso.

Table 1. Yield (kg/ha) and percent cowpea infested with Striga at different locations in West Africa in 1983

	Burkina Faso				Niger		Mali		Nigeria	
	Kamboinse		Ouahigouya		Magaria		Seno		Kano	
Varieties	Yield (Kg/ha)	Infest. (%)	Yield (Kg/ha)	Infest. (%)	Yield (Kg/ha)	Infest. (%)	Yield (Kg/ha)	Infest. (%)	Yield (Kg/ha)	Infest. (%)
KVx 30-141-1G	1469	1.0	467	0.0	347	2.6	1907	2.6	1500	31.4
KVx 30-166-3G	1408	0.0	383	0.0	237	2.0	2262	6.3	1928	6.7
KVx 30-183-3G	1567	0.0	400	0.0	222	2.8	2162	0.0	1367	11.6
KVx 30-199-4G	1397	11.0	317	0.0	333	2.8	1203	5.6	1488	33.2
KVx 30-312-3G	1289	7.7	467	0.0	278	4.9	1323	4.7	1395	27.2
KVx 30-323-1G	1266	10.3	417	0.0	195	0.0	673	2.1	1153	8.9
KVx 30-403-1G	1247	2.7	383	0.0	278	2.0	1017	8.4	1262	11.9
SUVITA-2	1486	0.0	450	0.0	375	5.0	1572	3.3	1650	9.0
58-57	1229	1.0	350	0.0	278	44.4	553	19.3	917	26.2
Mougne	826	87.3	150	15.9	205	45.8	550	28.1	1188	22.0
TN 88-63	1322	82.3	250	13.0	305	21.5	1033	44.7	1328	33.3
Local	84	63.3	0	19.5	222	35.6	392	21.0	383	23.6
Trial Mean	1212	22.2	367	4.0	273	14.1	1221	12.0	1297	20.4
C.V. %	19.1	47.7	23.4	-	38.0	13.6	35.9	10.7	20.2	89.5
LSD 5%	370	17.4	147	-	176	31.2	742	20.4	445	15.5

Table 2. Yield (kg/ha) and percent cowpea infested with Striga at different locations in West Africa in 1984

	Burkina Faso				Nigeria				Mali	
	Kamboinse		Ouahigouya		Kano		Bakura		Kaporo	
Varieties	Yield (Kg/ha)	Infest. (%)	Yield (Kg/ha)	Infest. (%)	Yield (Kg/ha)	Infest. (%)	Yield (Kg/ha)	Infest. (%)	Yield (Kg/ha)	Infest. (%)
KVx 30-166-3G	801	3.5	372	0.0	857	10.4	2494	49.4	355	13.6
KVx 30-183-3G	583	1.0	405	0.0	264	13.5	3234	51.0	365	0.0
KVx 100-1	977	0.0	243	0.7	1373	11.1	2445	32.2	543	11.9
KVx 100-2	988	0.7	355	0.0	1067	12.9	2015	37.1	741	16.7
KVx 68-1	657	22.7	260	4.3	1003	33.8	1506	71.7	469	13.8
KVx 68-2	569	0.0	190	25.7	889	35.6	1852	44.2	321	54.8
KVx 61-1	779	6.8	233	5.0	361	34.3	1383	54.7	420	21.3
KVx 61-2	1077	2.2	327	0.0	637	15.1	2014	38.7	141	15.9
KVx 61-3	525	25.3	196	22.0	1049	17.6	1679	56.5	839	38.7
SUVITA-2	1053	0.0	360	0.0	309	12.5	3383	51.5	400	17.8
Mougne	443	33.7	219	15.3	613	34.8	815	79.6	765	32.4
Local	276	64.0	63	20.3	1437	39.1	938	46.9	692	13.5
Trial Mean	725	16.0	267	7.8	821	22.6	2113	52.8	504	20.8
C.V. %	28.7	77.5	50.7	178.0	19.0	59.0	30.0	47.0	70.0	82.0
LSD 5%	345	21.0	230	24.0	263	22.7	1091	42.1	602	29.0

Table 3. Yield (kg/ha) and per cent cowpea infested with Striga at different locations in West Africa in 1985

	Burkina Faso				Niger				Nigeria		Mali	
	Kamboinse		Ouahigouya		Maradi		Magaria		Bakura		Kaporo	
Varieties	Yield (Kg/ha)	Infest. (%)	Yield (Kg/ha)	Infest. (%)	Yield (Kg/ha)	Infest. (%)	Yield (Kg/ha)	Infest. (%)	Yield (Kg/ha)	Infest (%)	Yield (Kg/ha)	Infest. (%)
KVx 30-166-3G	2249	1.0	1335	0.0	2004	10.9	1294	47.3	3300	13.3	585	-
KVx 30-183-3G	1414	0.0	935	0.0	1942	11.9	1169	27.1	3700	2.7	306	-
KVx 100-1	1061	0.0	923	0.0	1281	24.5	721	39.0	2833	41.0	557	-
KVx 100-2	1898	0.0	1445	0.0	2013	17.9	1013	52.0	2867	0.0	738	-
KVx 61-2	1702	0.0	838	0.0	1626	25.0	1019	47.7	2633	13.3	640	-
KVx 61-74	2443	0.0	1045	0.0	2005	28.9	634	49.8	2933	5.0	821	-
KVx 60-1	1948	0.0	1330	0.0	1658	37.3	807	59.8	1133	33.0	877	-
KVx 65-80	1449	0.0	849	0.0	1738	24.1	793*	50.0	1967	21.7	1002	-
KVx 64-54	2152	0.0	1568	0.0	1731	25.7	678*	40.1	2133	15.0	835	-
KVx 65-114	2499	0.0	989	0.0	1635	32.4	561*	47.8	2100	13.7	1016	-
KVx 65-119-2	1964	0.0	1135	0.0	1962	26.6	736	53.3	1667	35.7	891	-
IT82D-716	255	75.1	538	53.3	622	24.3	174	65.7	600	22.7	388	-
Mougne	1650	39.3	819	41.3	1295	27.5	388	76.4	1766	42.0	501	-
SUVITA-2	1961	0.0	772	0.0	2547	0.0	1187	44.7	3300	4.7	1141	-
Local	907	36.0	333	67.3	2200	24.6	1294	71.2	1067	38.7	47	-
Trial Mean	1704	10.2	990	10.8	1718	22.6	800	51.3	2267	20.2	690	-
C.V. %	19.1	107.5	42.2	77.4	14.9	31.1	26.8	20.9	39.2	115.8	26.4	-
LSD 5%	543	18.3	699	14.4	424	11.8	360	18.1	1485	39.0	304	-

* Varieties KVx 100-21-7-1, KVx 85-1 and KVx 183-2, respectively.

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SCREENING OF ADVANCED SORGHUM LINES

FOR RESISTANCE TO STRIGA HERMONTHICA IN CAMEROON

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SUMMARY

Host plant resistance to sorghum was demonstrated as early as 1920. However, its exploitation in breeding broad-spectrum, stable resistant cultivars was started only recently. Striga-tolerant genotypes have been identified under Striga infested plots in north Cameroon. Genetic analysis of field resistance in sorghum revealed that it is controlled predominantly by additive gene action, thus straight selection is effective. The pedigree approach to transfer the resistance into elite agronomic background genotypes is discussed. The need for future integrated Striga management including resistant cultivars and complementary agronomic control practices is emphasised.

INTRODUCTION

Sorghum is the main cereal crop grown in the semi-arid areas of north Cameroon. It is the staple food for the people of this zone. Its other uses include processing for beer and the preparation of local drinks. The stalks provide fodder, fuel and shelter material. The current production of sorghum in Cameroon is about 410 000 metric tons/year. Statistical data on area and production of cereal crops in north Cameroon are given in Table 1.

The primary objective of our research effort has been the breeding of suitable sorghum cultivars which lead towards the development of production systems of higher yield performance and stability across a range of environments. These cultivars should be disease and pest resistant, of good grain quality acceptable to farmers and tolerant/resistant to Striga and drought.

Until recently, Striga was considered as a trivial weed, not as the complex problem it actually is. As such, very little effort was made to effect its control. Many farmers are still not aware that Striga produces seeds and that its seed production can be checked by pulling it out before flowering.

Resistant varieties of sorghum were identified as early as 1920, but serious efforts to exploit them and develop stable and resistant cultivars started only recently. *Striga* is widespread throughout the semi-arid tropical regions of Africa and it is rare to find a sorghum field without a *Striga* plant. *S. hermonthica* causes serious losses in sorghum yield. Doggett (1965) estimated a reduction in yield of 1 kg for every 1000 *Striga* plants.

MATERIALS AND METHODS

During the 1982 cropping season, a farmer's field heavily infested with *Striga* was selected at Ndongkole near Maroua to initiate the screening of advanced sorghum lines for tolerance/resistance to *S. hermonthica*. To create an adequate *Striga* population, *Striga* seed collected from outside the trial was added every year before sowing. The *Striga* nursery established in 1983 included a sorghum-*Striga* trial from the ICRISAT program in Burkina Faso as well as agronomically superior breeding lines with a good level of *Striga* tolerance selected from the Cameroun National Programme. The nursery trial from ICRISAT consisted of sorghum cultivars selected annually for resistance to *Striga* in different African countries. Damougari, an exotic check (E 35-1), and susceptible check CK 60-B were grown in a randomised complete block design consisting of four replicates, during the 1983 and 1984 cropping seasons. In 1985, an improved variety, S-35, identified in our program, was also included in this trial after confirmation of its higher yield and stability across a wide range of environments in the semi-arid zone of northern Cameroon. The layout followed for the experiment was that of a checker board design developed at ICRISAT (Rao *et al*. 1981; Rao, 1985), the details of which are given in Figure 1. The number of entries in each replicate was 52 (12 test entries and 40 susceptible check plots).

RESULTS AND DISCUSSION

Field screening is very reliable provided the *Striga* infestation is uniform and regular over time, the experimental area is homogeneous and the experimental design and the criteria for evaluating resistance are appropriate (Ramaiah, 1981). Taking these factors into consideration, the results obtained during the three years 1983 to 1985 in north Cameroon are reported here.

Grain yield (kg/ha), days to 50% flowering, *Striga* count at harvest, panicle length and 1000 grain weight were recorded each year and were analysed statistically. The annual mean performance of some selected sorghum cultivars against *Striga* at Ndongkole are presented in Table 2. The mean sum of squares due to genotypes was found to be highly significant at the $P = 0.01$ level for grain and other traits whereas the *Striga* count per plot was found to be significant at $P = 0.05$ in all three years, indicating wide genetic variability among sorghum genotypes for these traits. The grain yield during the 1983 and 1985 seasons was very high because the rainfall distribution was uniform, whereas in 1984 the rainfall was very low and erratic when most of the genotypes, except for the very early maturing, failed to produce grain or yield was very low. Therefore, the short cycle (90 days to maturity) genotype S-35 was included as a check (Table 2).

The Striga count taken at harvest in the susceptible check genotype (see Table 2) indicated that the level of Striga infestation increased with time. The population increased from 316 plants/8-m^2 plot in 1983 to 492 plants/8-m^2 plot in 1985 in the susceptible check. This showed that each year there was a fairly high level of Striga infestation and certain tolerant genotypes were genuinely selected.

Phenotypic correlation coefficients between Striga count at harvest and yield as well as other yield components were estimated from the data taken in 1985. The correlation coefficient between Striga count and grain yield, as expected, was found to be negative and significant at the 5% level (-0.201* based on 88 observations). The relation between Striga count and 1000 grain weight was also found to be highly significant and negative (-0.428**). Thus the presence of Striga reduces sorghum yield.

Considering the overall mean performance over the years, the genotype S-35 ranked first and yielded 4031 kg/ha followed by 82-S-50 (2545 kg/ha) and Framida (2384 kg/ha). The above three genotypes appeared to be tolerant to S. hermonthica when compared with a Striga-susceptible check (CK 60 B). These genotypes therefore seem to be promising for further use in our hybridisation program.

Ramaiah (1981) also identified genotypes IS 8785 and SRN 4841 to be less susceptible to Striga in Cameroon. He further confirmed in 1984 that Framida and selection 82-S-50 (a derivative of the cross between IS 8785 and E 35-1) exhibited a very good level of Striga resistance, good seedling establishment and 50% higher yield than E 35-1 during 1982 and 1983 in on-farm tests in Burkina Faso. These results are in agreement with those obtained in the Striga nursery in Cameroon.

Sorghum resistance to Striga is controlled predominantly by additive gene action (Rao, 1981 and Ramaiah, 1984). Selection procedures like pedigree, back-cross and recurrent selection could therefore be effective. Improvement of resistant varieties of sorghum for various agronomic traits and maturity cycles was initiated in 1983 using pedgree and back-cross procedures. The various parents (from both local and exotic lines) identified for various traits such as grain yield and quality, maturity cycles, resistance to various diseases and pests, tolerance/resistance to Striga and drought were used in the crossing programme at Maroua and the breeding materials are currently in the F_1 to F_4 generations.

In addition to the breeding efforts already under way, work should be initiated to explore the possibilities of agronomically controlled measures in the near future in northern Cameroon. These should include the effect of crop rotation, nitrogen management, soil management, the role of herbicides and date of sowing, especially in the context of the presently available short duration improved genotypes. In conclusion, Striga resistant cultivars with appropriate complementary agronomic practices should be the most ideal control package.

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Table 1. Statistical data on cereal crop production in North Cameroon.

Crop	Year	Cultivated area (ha)	Grain yield (tons)	Grain yield (kg/ha)	Average (kg/ha)
Sorghum (rainy season)	1978 - 1979	320 840	266 710	813	701.0
	1979 - 1980	369 570	253 090	817	
	1980 - 1981	358 819	379 272	1057	
	1981 - 1982	377 250	291 325	772	
	1982 - 1983	386 767	309 412	799	
	1983 - 1984	389 747	374 680	901	
	1984 - 1985	330 996	215 445	650	
Sorghum (Muskwari)	1978 - 1979	128 110	117 220	915	702.2
	1979 - 1980	121 840	92 815	762	
	1980 - 1981	133 636	132 290	985	
	1981 - 1982	111 195	60 343	542	
	1982 - 1983	109 722	54 860	499	
	1983 - 1984	114 612	63 957	558	
	1984 - 1985	67 242	44 000	654	
Pearl Millet	1978 - 1979	41 450	24 950	602	536.0
	1979 - 1980	47 820	24 925	521	
	1980 - 1984	-	no data available	-	
	1984 - 1985	55 871	27 340	489	
Maize	1978 - 1979	39 760	28 610	719	985.0
	1979 - 1980	38 406	36 660	954	
	1980 - 1981	22 331	25 279	1132	
	1981 - 1982	54 430	43 095	948	
	1982 - 1983	69 576	78 230	1124	
	1983 - 1984	92 058	95 177	1033	

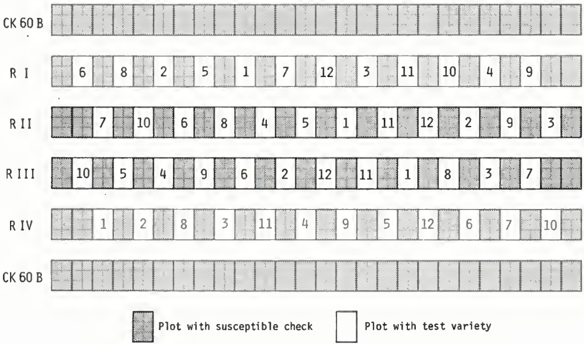
Source: Provincial Delegations of Agriculture

Table 2. Yield of selected sorghum cultivars in the presence of Striga at Ndongkole location, Maroua, Cameroon in 1983, 1984 and 1985.

	1983		1984		1985		Mean	
Selected Entries	yield (kg/ha)	Striga* nos.	yield (kg/ha)	Striga* nos.	yield (kg/ha)	Striga* nos.	yield (kg/ha)	Striga nos.
82 - S - 50	4419	422	304	100	2914	158	2545	226
FRAMIDA	2990	385	800	486	3363	267	2384	379
E 35 - 1 (Exotic check)	2631	345	343	85	--	-	1487	215
DAMOUGARI (Local check)	3443	387	117	364	--	-	1780	375
S - 35	--	-	-	-	4031	185	4031	185
CK 60 B (Susceptible check)	1208	316	445	381	936	492	863	396
C.V. (%)	930	80	765	388	897	263		
LSD (5%)	25.6	20.8	72.5	119.8	36.8	41.8		

*Number of Striga plants/8 m

Fig. 1. Plan of International Sorghum *Striga* Nursery.



COORDINATED INTER-AFRICAN PHYTOSANITARY REGULATIONS FOR WEED CONTROL WITH SPECIAL REFERENCE TO STRIGA

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NATURE OF THE PROBLEM

Striga, a plant recognised as a weed since the beginning of this century, has unfortunately not been subjected to any extensive research.

At present, one can safely say that no effective control technique has been proposed to small-scale African and Asian farmers, who can only endure the damage caused to their food crops by this pest, which has the following characteristic features:

It is a member of the family Scrophulariaceae and an obligatory parasite meaning that it depends upon the host plant whose roots it attacks. Among the 30 annual species recorded, three are especially harmful. They are Striga asiatica and S. hermonthica, which parasitise sorghum, millet, maize, sugar cane and rainfed rice according to regions, and S. gesnerioides, which causes serious damage to leguminous plants, tobacco and sweet potato.

STRIGA: A PERMANENT THREAT

From a study of the biology of this weed, one can appreciate the extent of the threat it poses. The minuscule seed of Striga which is buried in the ground remains dormant during the dry season. Then, with a temperature and moisture which are generally favourable at the beginning of the rainy season, the seed undergoes a pre-conditioning period of between 10 and 15 days during which it acquires the capacity for germination.

If the seed is between 2 and 5 mm from the roots of a host plant, it receives a germination stimulant from this host plant which enables it to start its vegetative life. It thus grows a radicle which, by chemotropism, is directed towards the root of the host plant. When this radicle reaches its target, it attaches itself onto the root of the host.

Next it develops a haustorium, a kind of suction organ which enters the root and sets up vascular connections with the host.

Striga then acts as a sort of pump, drawing water and minerals from the host plant as well as organic substances necessary for its growth. This parasitism is so cunningly carried out that Striga remains hidden in the ground for several weeks before its plantlet appears. The appearance of the first leavea enables Striga to manufacture its own food by phyotosynthesis but this does not prevent it from continuing to draw profusely on the host plant.

Within a few weeks, Striga grows, blossoms by producing very attractive flowers which eventually produce abundant seeds (from 400 000 to 900 000 seeda per stem according to the species). During this period, the host plant, which is subjected to these withdrawals of its food and to the toxic and pathological activities of Striga, withers, has a decreased growth rate and, in the case of heavy infestation, eventually dies.

ASSESSMENT OF LOSSES

Losses in output caused by Striga seem difficult to assess because part of the parasite remains hidden. In addition, these losses vary greatly according to the resistance capability of the host plant, climatic conditions and the level of infestation. Nevertheless, it is estimated that in the semi-arid region of Tropical Africa, Southern Africa and India where Striga is very widely spread, losses in cereals reach 60 to 70%. According to Leplaideur (1986), this is the case with sorghum in Sudan and Nigeria and the Andhra Pradesh State in India.

It seems that in this last region and in Ethiopia, some lands are so heavily infested that farmers are compelled either to change crops, if this is possible, or to abandon their fields and farm elsewhere.

The accidental introduction of Striga into the United States caused serious damage to over 150 000 ha of land in the south of the country in 1956.

STRATEGIES FOR STRIGA CONTROL

For African farmers in particular, Striga appears to be a major problem which, even though it has always existed, now seems to have assumed greater proportions. In the most densely populated regions, the reduction of fallow and the cultivation of very poor lands encourage the spread of Striga which grows well in deteriorated soil. In addition, the improved varieties of crops that have been introduced are less resistant to this parasite than are the local varieties. So, in India, where Striga was only a marginal problem to farmers who traditionally cultivate sorghum, the continued introduction of new varieties has encouraged a renewed outbreak of the infestation which, in its turn, affects local varieties.

It is certainly no easy matter to eradicate this weed. Indeed, these thousands of very small, light seeds which can be easily carried in the wind have, in addition, the ability to remain in the soil for periods of 15 to 20 years without losing their viability while awaiting favourable climatic conditions and the presence of a host plant.

To control this parasite effectively, it is not enough to prevent its reproduction; it is also necessary to reduce the stock of seeds in the soils of the infested regions.

The Americans have developed some fairly effective chemical products but due to the potential danger involved in application and the high costs, these cannot be used by farmers in developing countries. The viability of dormant seeds in the ground can be destroyed with methyl bromide, but the technique used most often is the stimulation of germination with ethylene gas. In the absence of any host plant, the germinated seed dies after 4 days. A single treatment destroys 90% of seeds in the ground.

Other products, such as strigol extracted from the root of the cotton plant, fulfil the same role but they are very onerous for the time being. Post-emergence herbicides are difficult to use; they should be specific in order not to destroy the host plant and should be applied for many successive years in order to reduce the infestation significantly. In spite of all their efforts, the USA have not succeeded in destroying Striga which still infests 90 000 ha of land.

Other serious research undertaken mostly in India by ICRISAT has dealt with the resistance of certain varieties of sorghum to Striga. Many varieties are not so effective in stimulating germination of the parasite and some others are able to resist the penetration of the haustorium into their roots. The results of selective breeding are not yet entirely satisfactory because the resistant varieties have poor agronomic qualities. In addition, this resistance often breaks down after a few years because some Striga species succeed in adapting to these host plants. Breeding is made even more difficult since selection depends on the level of Striga infestation which varies from year to year and could range from heavy to none at all; furthermore, a susceptible plant in one location can be resistant in another. These problems merit further study.

Biological control is far from being operational. Some insects were introduced from India between 1974 and 1979. By laying their eggs on the flowers of Striga, they reduced the number of Striga seeds to a great extent, but it has been difficult to evaluate the results. Work is presently being carried out on the introduction of some fungus which could attack the plant and cause its destruction.

Among the agronomic control measures, many have limited efficiency and are less adapted to the socio-economic conditions that prevail in most of the affected regions. The short cropping season in Africa does not allow, for example, the development of a rapid growing plant which can be destroyed as soon as Striga germinates. Trap crops and pseudo-hosts generate suicidal germination of Striga but they do not destroy it completely. Cotton, groundnut, sunflower and cowpea can fulfil this role according to the regions and the species of Striga; but they should be grown over a number of years to destroy the seeds entirely.

In the case of a light infestation, crop rotation for one year will bring noticeable improvement. Similarly, the application of nitrate fertilizer enhances the development of the host plant at the expense of the parasite by restraining the growth of the radicle but the rates recommended for Striga elimination are too high for the crop.

At the moment, there is only one realistic technique that can be recommended to African and Asian farmers in light infestations on small farms and that is hand-weeding of Striga stems every 10 or 15 days in order to avoid the setting of seeds.

COORDINATED INTER-AFRICAN PHYTOSANITARY MEASURES AGAINST STRIGA

It is necessary that all West and East African countries should develop an integrated Striga project encompassing every aspect of Striga control in studies to be carried out as follows:

National Level:

preparation of an accurate inventory of Striga species and their distribution;

evaluation of potential factors both objective and subjective which foster the spread of these weeds;

introduction of phytosanitary control of seeds of the host plants when imported or exported;

establishment of teams of experts on Striga and other weeds, within national plant protection and research services;

strengthening of the teaching of weed science in Schools of Agronomy.

International Level:

encouragement of exchange of information on weed science among African, Asian and European research workers;

intensification of sensitisation of agricultural populationa and farmers of the danger of these parasitic plants indicating the precautions to take when transporting plants and seeda of potential host plants from one country to another.

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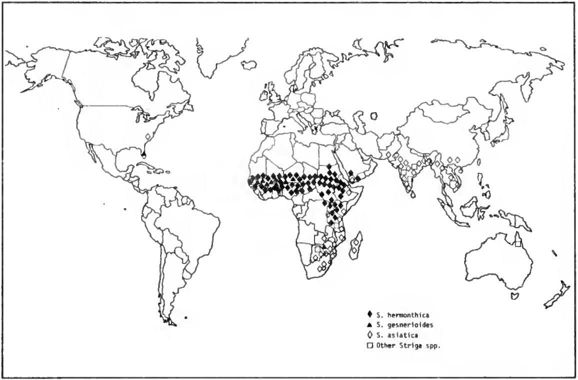
Fig. 1. Map of the World showing the distribution of Striga species



IMPROVED PACKAGE FOR STRIGA CONTROL FOR THE SMALL SCALE FARMER

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INTRODUCTION

Most weed scientists accept that every agricultural practice develops its own set of weed problems. Over the ages, the traditional crop production practices of burning, dry season fallowing and surface cultivation have been biologically efficient methods of depleting soil fertility and reducing the ability of soils to absorb and retain moisture. In the trend towards desertification, survival weed species were invariably perennials, physiological xerophytes (species with a high ratio of roots compared with foliage), adaptive annuals and parasitic weeds. Such a trend occurred particularly in unimodal rainfall areas.

Improvements offered to the small-scale farmer over the last three decades have generally exacerbated his overall weed problem and ensured the propagation and survival of *Striga* species. The role of these so-called improvements in developing the *Striga* and *Striga*-weed complexes may be summarised briefly under the following headings:

IMPROVEMENTS IN MECHANISATION FOR LAND PREPARATION/WEEDING

The main disadvantages have usually been:

to increase the overall weed problem resulting from a greater ability to shift more soil in land preparation/weeding;

to expand the area of weeds per unit area to be controlled, by adopting row-cropping rather than inter-cropping. This is particularly the case for wide row spacings;

to improve the ability to control the less important inter-row weeds rather than the far more damaging in-row weeds;

to distribute weed seed more uniformly through the soil profile: cultivating immediately post-harvest ensures that the maximum number of weed seeds are returned to the soil;

to further the decline in soil fertility.

Overall, the foregoing improvements utilise about 20% of available improved weed management technology, encourage more difficult-to-control weeds, and are based on the age-old adage of growing weeds to control weeds.

NEWER VARIETIES

In comparison with traditional varieties, most new cereal varieties need to be weeded twice as early, twice as often and support up to twice the weed weight. Further, traditional varieties selected since the dawn of agriculture show some resistance to the local ecotypes(s) of Striga. In contrast, the widespread use of a uniform genotype of a cereal is now recognised as one of the wide and significant causes of the increase in Striga (see At ICRISAT No. 13) coupled with the earlier requirement for weeding which allows the unrestricted development of Striga. Root damage by weeding practices may also favour Striga establishment.

NUTRIENTS

There are few data to suggest that a vigorously-growing host plant is less severely attacked by Striga than a nutrient-deficient plant of the same variety. The overall effect of nutrients, particularly some forms of nitrogen, appears to be secondary in suppressing Striga development.

THE FAO PACKAGE

The objective of this package is:

to simplify land preparation/weed management to a level where improvements are acceptable and capable of being adapted by the small-scale farmer.

In practical terms this is based on the simple expedients of:

encouraging minimal weed growth by disturbing the smallest quantity of soil per unit area for seed-bed preparation. If soil type demands it, a 20-cm wide strip 'in-row' is cultivated;

planting with further minimal disturbance of the soil;

applying fertiliser in the row;

establishing the 20-cm in-row area absolutely free of weeds;

weeding the inter-row area (which has not been disturbed so that minimal weed growth is encouraged) after the weeds have inhibited Striga growth by shading and/or serving as a trap crop;

utilising where possible newer varieties with some tolerance to Striga, provided that variety is acceptable to the small-scale farmer;

selectively controlling the in-row Striga as it appears;

Where chickpea is inter-cropped, the same package applies.

THE ROLE OF HERBICIDES

The effect of cultivation is to establish the highest number of weeds per unit area.

The effect of herbicides is to utilise inputs more fully by the timely and efficient control of all weeds resulting from cultural practices.

In the FAO package, about five percent of the normal rate of herbicide application is utilised within the 20-cm in-row strip to enable the crop to be established weed-free and to make fuller use of available nutrients and moisture. If and when Striga appears in-row, a weak solution of herbicide is selectively applied as an early control measure.

DISCUSSION AND OVERALL ADVANTAGES

Normally with traditional and improved mechanical methods, 40 to 60 percent of cropping activity in Striga areas is needed for land preparation/weeding. Much of this activity is directed towards growing weeds that animal and human resources cannot control in time and adequately to ensure full yields. Further fertiliser inputs within the row increase weed competition many fold within that area.

It is not fully realised that a 20-cm strip in-row takes approximately 15 days per hectare to weed manually, and up to three manual weedings may be required. Inter-row weeds may be removed mechanically for the same area within a day or so. Many small-scale farmers within African nations are efficient inter-row weeders but highly inefficient in-row weeders (labour x availability x removing competition early enough is impossible). Thus, for instance, in Niger about 30 percent of the millet crop is not weeded and the balance not weeded to maxima.

The FAO package (on a per hectare basis) is designed so that a single farmer unit is able to prepare the seed-bed, plant, fertilise and weed in-row in two to four days for the food crop and undertake similar activity for the cash crop, thus taking full advantage of short growing seasons. The package is based on an integrated cropping system approach where the inputs (in general descending order of priority) are: land preparation/weed management to varieties to fertilizers to other plant protection activities. Where moisture deficits prevail, many weeds have a greater potential to utilise available moisture than improved crop varieties, and this increases the need to establish the crop weed-free and to lessen the severity of damage from Striga.

Within the CILSS Project in the Sahelian area, the FAO package now has three years standing at the village and adaptive research levels in the Gambia. In Niger, adaptive research has been conducted for the same period. In Gambia, where a high proportion of the cereal crops is affected, it is possible to reduce a high 40 percent of yield loss by Striga and Striga-weed complexes to a low 10 to 15 percent.

The ultimate package calls for cropping in a permanent 20-cm in-row strip, where weeds, until the fertility status can be reached to support more useful inter-row ground cover, form the suppressant for Striga and Striga-weed complexes. The overall programme is based on vegetation management which is the antithesis of encouraging weed growth by cultivation. The resulting weed growth developed by cultural practices cannot usually be controlled adequately other than with high input and costly technology.

It is pleasing that the FAO package for Striga and Striga-weed complexes will be adopted in the Cameroon under a UNDP Project. The objective of this Consultation is to make known the fact that Striga and Striga-weed complexes can be controlled utilising methods capable of being accepted and adapted by the small-scale farmer. Further, when this methodology is applied, it is possible to go directly from traditional practices to vegetation management thus largely by-passing the costly steps of full mechanisation/full herbicide-use normally recommended under high input technology.

NATIONAL PILOT PROGRAMME FOR STRIGA CONTROL IN CAMEROON

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Agriculture in Cameroon employs about 70% of the active population. Cereal crops constitute the major staple diet in Cameroon particularly in the North where most of the holdings are cultivated by small-scale farmers. One third of the country's population lives in the North.

Cereal crops of maize, millet, sorghum and upland rice are severely attacked by Striga species in this zone. Preliminary assessment of crop damage in 1984 revealed that some 300 000 hectares of maize, sorghum and millet were severely damaged by a very high and uniform Striga population. Yield loss in some heavily infested fields was as high as 90%, and it is estimated that two-thirds of the land under cultivation in northern Cameroon has a high build-up of the seed of the parasitic weed.

The Striga problem, which is threatening the livelihood of a large sector of Cameroon's population and that of the refugees fleeing from neighbouring Chad, is of major concern to the Government. Agriculture in nothern Cameroon is already weakened by the effects of drought and the depredations caused by grain-eating birds and locusts.

One of the Government's primary objectives is to ensure sustained food self-sufficiency for Camero nians by reducing pre-harvest losses and increasing domestic food crop production. In view of the magnitude and complexity of the Striga problem, the Government requested FAO assistance in strengthening plant protection activities for Striga control in Cameroon. In response to this request, FAO in conjunction with OAU organised a Striga Workshop, held in Yaounde from 23 to 27 September 1985, in which FAO was encouraged to undertake a supporting and coordinating role in Striga and Striga/weed complex control. We are pleased to announce that, with FAO as the executing agency, UNDP has committed 400 000 US dollars for a two-year National Pilot Programme for Striga control in Cameroon.

This project, during its first two years of operation, aims to:

1 assess the economic importance of Striga species and Striga/weed complexes on cereal production in Cameroon;

2 design efficient control methods that can be adapted within the cropping systems of the small-scale farmer in Striga-affected areas;

3 strengthen the crop protection sector in the Ministry of Agriculture and ensure collaboration with national research institutions, namely Institut de la Recherche Agronomique (IRA) and NCRE;

4 document the findings and disseminate information to all parties concerned.

In order for the project to achieve its objectives and to ensure the transfer of technology to farmers' fields, a strong extension training and research component is envisaged. The project will, therefore, undertake to:

(a) set up a Striga Task Force comprising representatives from the Ministries of Agriculture and Research as well as the Institutions concerned;

(b) train 25 research and extension specialists in Striga/weed management in addition to one M.Sc. fellow at a university in Nigeria;

(c) implement Striga/weed management practices in farmers' fields.

However, Cameroon is only one of 14 countries in West and Central Africa seriously affected by Striga. Measures, including plant quarantine, must be taken to ensure that this parasite does not spread further within countries where it is still only a minor problem or to areas where it does not yet exist. It is expected that the Cameroon project will serve as an example, and the technology developed will be transferred to other countries where the problem is equally serious. Therefore, the pilot project started here should be linked to a sub-regional Striga control programme for West and Central Africa.

The future of Striga control will depend very much upon the formation of a regional Striga control programme for Africa, one that will ensure continuity and stability of bilateral programmes in individual countries. Once established, this programme will form the basis of an inter-country network of collaboration at a regional level, enabling participants to exploit resources and the expertise of scientists and specialist organisations in the region, not normally available within any one national programme.

We are, therefore, appealing to all those present (crop protection specialists, representatives from specialised institutions and donor countries) to put their heads and minds together in order to formulate a workable, regional, Striga control programme that will increase the production of the cereal crops which constitute the staple diet of millions of Africans.

Musicians in America and Europe have played and sung, and athletes have run across several continents to help relieve famine in Africa but, as we all know, these were short-term gestures. With the continuing encouragement and financial support of UNDP, FAO and other generous international organisations, and with the wealth of scientific experience at our disposal, plus our own capability and willingness to succeed, we can do something to ensure prosperity.

A REGIONAL PROGRAMME FOR STRIGA CONTROL IN WEST AND CENTRAL AFRICA

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INTRODUCTION

The poor performance of African agriculture has recently become a major issue of international concern. Almost all of sub-Saharan Africa experiences chronic food shortages requiring substantial food aid and food imports. In 1984/85, FAO identified 21 countries as having critical food supply problems. The combined cereal production of the 21 countries for the same period was 23% below normal. The long-term prospects for these countries as well as the rest of the continent remains uncertain.

Low level technology, lack of technical packages suited to the problems of small farmers, weak support services and the lack of proper incentive schemes, aggravated by hostile environmental conditions have interacted to produce this present situation.

Basically, three approaches are commonly proposed to resolve the region's food problems. The first of these is increasing the area of land under cultivation. The second is increasing yield from the land being cultivated. The third is reducing the pre- and post-harvest crop and food losses due to pests, which are severe and commonly exceed 40%, but are often accorded low priority in the development programmes and strategies of African Governments.

It is estimated that most of the food grown in Africa is produced by traditional farmers who constitute 80 to 90% of the population. Significant increases in food production would therefore seem possible if the appropriate technology together with the necessary production inputs and incentives were provided to the great majority of the small-scale farmers. A greater part of the labour of these farmers is devoted to the clearing of land and to hand weeding. At present it is estimated that 80% of African farmers spend between 40 to 60% of their total agricultural effort on land preparation/weed control.

The methods being used to control weeds are now known to be the most biologically effective means of depleting soil fertility and reducing the capacity of soils to absorb and retain moisture. Further, as the soils get more depleted, greater resistance in weeds is developed and for the more resistant species such as Striga, the traditional farmer has very little means of control.

African agriculture will therefore benefit greatly from increases in land productivity through the reduction of the labour constraint in weeding and the development of an integrated management system of weed control methods adapted to the needs of the various agro-ecosystems.

This paper will attempt to review the overall problem of weeds and in particular the parasitic weeds of the *Striga* genus in West Africa and to identify factors responsible for the increasing crop losses caused by *Striga* and to propose an agenda for a Regional Action Programme.

STRIGA AS A PROBLEM IN WEST AFRICA

Striga affects the livelihood of some 300 million people in Africa, with 17 countries being seriously affected and a further 25 where moderate damage occurs. The crops most seriously affected are millet, sorghum, maize, upland rice, sugar-cane and cowpeas. Millet and sorghum damage is in the order of 10-40% with maize being the most severely damaged crop. Losses in maize production are frequently 60% or higher.

Seldom has the full impact of *Striga* damage been realised, as a high percentage of the damage occurs before the *Striga* plant emerges from the soil. Severity of damage is often related to the density of *Striga* plants per unit area.

Striga is a serious problem in all the countries of West and Central Africa with the exception of Sierra Leone and Liberia. The Sahel Savanna region is hardest hit because, in addition to cereals, leguminous crops such as cowpea and groundnuts are also parasitised.

The problem is more serious in some countries than in others only in terms of its distribution while its effects on food production in general are similar wherever it occurs. For example, *Striga* is present in all areas under cultivation in Benin, Burkina Faso, Niger, Mali and Togo, whereas, in other countries, the distribution is confined to areas in the Northern Savanna zones. This situation however is changing: there is evidence that the parasite is being introduced to areas in the south where a few years ago it did not exist. In Côte d'Ivoire, rice is the most important cereal crop; this crop is now threatened by *Striga* in areas below latitude 8°. Côte d'Ivoire also produces seed rice for distribution to neighbouring countries.

The general belief that *Striga* is a problem associated with drought, low soil fertility and contained only in the Sahel is no longer valid. Recent investigations in Guinea revealed that farmers growing fonio (*Digitaria exilis*) in areas with a mean annual rainfall of 1,500 mm were forced to abandon their farms because of a high infestation by *S. aspera*. This species has been shown to adapt quite easily in high rainfall areas and is capable of growing in waterlogged conditions. There is evidence of total failure of a crop of lowland rice in an area that was flooded throughout the growing period. S. asiatica is the only species recorded in southern Togo, an area with a bimodal rain pattern where the potential yield loss of maize, attributed to the parasite, has been estimated at 90%.

Soil fertility is generally not a problem where rice is cultivated. Maize grown under good management practices usually receives adequate fertilisation; irrespective of this, studies have shown that maize suffers more damage under Striga attack compared with sorghum and millet.

Striga is a limiting factor to food production in land-locked countries like Burkina Faso, Niger and Mali. The bulk of the carbohydrate consumed in these countries comes from cereals like sorghum, millet, maize and rice. In addition to the animal protein, which is sometimes unaffordable in many communities, cowpea provides a good source of dietary protein. However, potential yield loss of these crops in farmers' fields due to Striga alone is between 40 and 100%. The Striga problem in these areas is often aggravated by climatic conditions and poor agronomic practices. In the majority of cases, the level of input is quite low, comprising mixed cropping systems with no fertiliser, no chemical control of diseases, pests or weeds and no soil conservation measures. This has resulted in socio-economic consequences and there are reports in several countries of the movement of farmers and cattle into neighbouring countries where the problem is less acute.

There is hope for resolving this plague that threatens the livelihood of millions of people in Africa. Striga can be contained at a level that will not result in famine and the migration of the farming population. Soils in Africa are already heavily infested and for a long time to come the parasite will not be eradicated; however, measures can be taken to improve the yield potential of the crops grown in these infested soils.

Traditional farming practices in Africa have contributed more than anything else to the growing problem of Striga. Traditional methods of land preparation, burning, dry-season fallowing and surface cultivation have been shown to be the most biologically efficient methods of screening out survival species such as Striga by depleting soil fertility and by reducing the ability of soils to absorb and retain moisture.

The widespread incidence of Striga is also attributed to the susceptibility of most of the improved varieties of cereals compared with traditional varieties; even though most international research programmes' have put more emphasis on the long-term objective of breeding more resistant varieties.

Although some success has been claimed, to date no applicable results are available.

A review of *Striga* control methods presently available to the small-scale farmer in West Africa has shown that, at present, there is no single method available to control *Striga*, which is both effective and economically feasible. Instead, control measures must involve a long-term, integrated approach with soil improvement/conservation being the end point against *Striga* damage. Improved land preparation for weed management must serve as the initial thrust along with the agronomic inputs of more tolerant varieties, nutrients and chemical control. Where an integrated approach has been adopted, yields have been increased significantly and succeeding crops have been less severely attacked.

FAO initiatives in West Africa in the last three years largely utilising simplified methods of land preparation and weeding adapted to the means and capabilities of the small-scale farmer, have shown that a high incidence of the parasite can be reduced to a low 10 to 15% of the total damage with significant yield increases. These findings were further developed at the joint OAU/FAO *Striga* Experts' Workshop held in Yaounde, Cameroon from 23 - 27 September 1985 and packages for *Striga* control suitable for use by the small-scale farmer were developed for immediate pre-extension on-farm demonstrations within the framework of national programmes. The first of such national programmes will commence soon in Cameroon with UNDP assistance. More effort is now needed to develop and implement various national *Striga* control programmes in West Africa and to coordinate these efforts within the framework of a larger regional programme which can also serve as a focal point for international collaboration on *Striga*.

A regional project initially for a duration of five years is proposed during which it should be envisaged to set up formal co-ordinating mechanisms at the regional and international levels to develop packages for *Striga* control and promote their adaptation at the farmer level through National Weed Management Programmes, provide training at national and regional levels, co-ordinate and support priority areas of adaptive research on *Striga* and disseminate information on *Striga* problems and control within and outside the region.

The project will not be research orientated. Rather, it should demonstrate and implement *Striga* control packages through National Plot *Striga* Control using the FAO *Striga* control package that was developed at the *Striga* Workshop in Yaounde. The package offers the small-scale farmer a simple system of land preparation/weeding for crop establishment that is acceptable and capable of being adapted at the local level and that will reduce the burden of high labour input, increase the probability of more timely crop establishment, increase yields and reduce the Striga problem. It is in fact based on a full-cropping systems approach where the general order of importance (from most to least) is: land preparation/weeding - varieties - fertilisers - other plant protection inputs.

Improved land preparation/weeding is based on the following:

moving/shifting the minimum amount of soil within the crop row - a 20-cm band for crop establishment;

establishing the crop weed-free within the 20-cm crop row;

permitting the weeds in the undisturbed inter-row area to establish to a stage where they serve as a catch/trap crop for any Striga establishing between the rows;

controlling the limited Striga establishment within the 20-cm crop row, preferably chemically by spot-application utilising a simple hand sprayer.

The FAO package has been initially tested in the Gambia with very promising results (see the paper by A Carson, Research and development strategies for the control of Striga hermonthica in the Gambia, page 89).

The project will assist participating countries directly in the establishment and strengthening of national Striga control units/programmes through which the FAO package will be tested, adapted, improved and implemented through pilot demonstrations at farmer level. Apart from the technical back-dropping to be provided by FAO, the project will collaborate closely with the national and international research institutes, namely IITA, ICRISAT and SAFGRAD. It will encourage cooperation between countries in their efforts to find solutions to a common problem - Striga.

ACTION PROGRAMME FOR STRIGA CONTROL IN AFRICA

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Bearing in mind the complexity of the Striga problem in Africa, the wide extent of the affected zones, and the yield losses in cereal production caused by different species and races within species of the parasite, the themes outlined below should be considered in the implementation of an action programme for Striga control in Africa.

II TRAINING

a) **MSc** For the severely affected member countries:

CAMEROON

NIGERIA

BENIN

1st Year: TOGO GHANA MALI NIGER SENEGAL

2nd Year: COTE D'IVOIRE GAMBIA GUINEA BURKINA FASO

Technical Support: OAU/FAO/IARC

b) **Technical Personnel:** National Programmes

c) **Farmers:** National Programmes

II APPLIED RESEARCH

a) **Agronomy:** National Programmes and Scientific Research Institutions, IARC (IITA, ICRISAT) SAFGRAD

b) **Selection of Resistant Varieties:** IARC (IITA/ICRISAT) SAFGRAD in collaboration with National Programmes

c) **Technical Control:** FAO/OAU/IARC/National Programmes

d) **Biological Control:** IARC

III EXTENSION/DISSEMINATION

National programmes OAU/FAO and bilateral programmes:

Demonstration plots in the field

Farmers' plots

IV PHYTOSANITARY LEGISLATION ON STRIGA

By the governments of interested countries

The agencies involved are as follows:

a) **Administration:** OAU/FAO/Individual countries

b) **Research Institutes:**

ICRISAT/National programmes (sorghum, millet)
IITA/National programmes (maize, cowpea, rice)
CYMMIT/National programmes (sorghum, millet)
SAFGRAD

c) **Demonstrations in the field:**

National programmes/OAU/FAO/IARC

d) **Dissemination of results:**

National programmes

e) **Donors:** Meeting in consortium

UNDP
USAID
GTZ
IDRC
Japan
World 2000

PART V

APPENDICES

APPENDIX I

ALL-AFRICAN GOVERNMENT CONSULTATION ON STRIGA CONTROL

Maroua, Cameroon, 20 - 24 October 1986

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APPENDIX II

MOTION OF THANKS

The participants expressed their thanks to the Government and people of Cameroon for having accepted to host the All-African Government Consultation on *Striga* Control. They further expressed their appreciation for the excellent facilities put at their disposal and for the cordial reception extended to them.

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